

A SAFETY MONITORING SYSTEM FOR COAL MINING WORKERS USING LORA

A Project Report Phase – II

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering Degree in Electronics and Communication Engineering

by

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of AITHA RANADHEER (39130014) and B. CHANDRA MOHAN REDDY (39130058) who carried out the project entitled “ A SAFETY MONITORING SYSTEM FOR COAL MINING WORKERS USING LORA” under my supervision from September 2022 to October 2022.

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DECLARATION

We AITHA RANADHEER (39130014) and B. CHANDRA MOHAN REDDY (39130058) hereby declare that the Project Report entitled “**A SAFETY MONITORING SYSTEM FOR COAL MINING WORKERS USING LORA**” done by us under the guidance of Dr. S. Karthikeyan, M.E., (Ph.D.), Assistant Professor, Department of Electronics and Communication Engineering, at SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, CHENNAI is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in **ELECTRONICS AND COMMUNICATION ENGINEERING**.

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ABSTRACT

These days mining workers' safety has become a major concern. They undergo various situations like high temperature and humidity, release of harmful gases and heavy vibrations which are very dangerous during mining in the underground mines. The project is intended to design a safety monitoring system for underground mining workers. In this project, a system is built using different sensors to monitor both surrounding and health parameters of miners such as temperature and humidity, release of harmful gases and vibrations. This system drives all the sensed parameters/values to the control hub using LoRa communication technique. This data is continuously observed by the controller unit and also if any critical situation is faced by the miner, an alert is sent to the control unit. The values that are detected will be displayed on the connected monitoring device which will be easier for the control center to monitor and take the instantaneous action to prevent miners from severe damages.

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CHAPTER 1

INTRODUCTION

These days the safety of mining workers is a significant challenge. Miner's health and life are helpless against a few basic issues, which incorporates the working environment, yet it is a delayed consequence. The process of Underground mining operation through human laborers is a highly unsafe scenario where the risks increase with the increase in distance from the ground. The mining operations with unsafe manners are due to different methodologies utilized by the miners for extricating diverse minerals. The longer the mine, the more prominent is the hazard. The safety measures execution is very poor, especially in the coal mine industries.

The coal mines have numerous risky stipulations that include high temperature and humidity, discharge of destructive gases that make unsafe surroundings for specialists working there. Many employees are taking off their occupations in coal mines or no longer at all inclined to pick such employments as mining. This creates a lot of challenges in the accessibility of employees for the coal mining industry. The security of laborers working in coal mine industries is increasing day by day through technologies.[11]

The accidents of calamities in coal mines are mainly due to the harsh environments and unsafe working conditions. This makes the need of employing mine checking systems at a high level for coal mines. It is quite hard to analyze all the environmental conditions constantly in a coal mine manually. So, we have introduced a system which is built using different sensors used to monitor both surrounding and health parameters and drives all the sensed parameters/values to the control center through LoRa.[14]

The system can consist of various sensors that collect data on these parameters and transmit the data wirelessly to a central hub using LoRa technology. The central hub can then analyze the data and provide real-time alerts and notifications to mine operators in the event of any safety issues. Implementing a safety monitoring system using LoRa can provide several benefits.

A safety monitoring system for coal mining using LoRa is a modern and innovative system that utilizes wireless communication technology to ensure the safety of miners during the mining process. This system uses LoRa sensors to collect data on various environmental factors such as temperature, humidity, gas concentration, and air quality, as well as the location and movement of miners. The collected data is then transmitted wirelessly to a central monitoring system that can be accessed by mine management teams.[12]

The collected data is then transmitted to a central monitoring system, which can be accessed by the mine management team. The management team can use this information to monitor the working conditions of miners and detect potential safety hazards, such as gas leaks or high temperatures.

The monitoring system allows mine management to monitor the working conditions of miners in real-time and detect potential safety hazards, such as gas leaks, high temperatures, or poor air quality. The system can also alert management and miners through alarm systems and personal alert devices in case of an emergency, ensuring quick response times and reducing the risk of injury or loss of life.[13]

In case of an emergency, the system can alert the management team and miners through alarm systems and personal alert devices. This enables quick response times, reducing the risk of injury or loss of life.

LoRa technology, which is a long-range, low-power wireless communication technology, is used to transmit this data wirelessly to a central monitoring system. This allows mine management to monitor the mining environment in real-time and detect potential safety hazards before they become a threat to miners. In addition to environmental sensors, the safety monitoring system also includes sensors that track the location and movement of miners. This helps to ensure that miners are working in safe areas and are not in danger of being trapped or injured. The system also includes personal alert devices that miners can wear on their person. In case of an emergency, these devices can be used to alert mine management and other miners of the situation, ensuring quick response times and reducing the risk of injury or loss of life.[15]

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management and other miners of the situation, ensuring quick response times and reducing the risk of injury or loss of life.

One of the key advantages of a safety monitoring system for coal mining using LoRa is that it allows for real-time monitoring of the mining environment. This means that any potential hazards can be detected and responded to immediately, preventing accidents and improving overall safety.[1]

The system also generates a large amount of data, which can be analyzed to identify trends and patterns in the mining environment. This information can be used to improve mining processes and optimize safety procedures, leading to increased efficiency and reduced costs.[12]

Some advanced features that can be incorporated into a safety monitoring system for coal mining using LoRa include:

- Real-time data monitoring: LoRa-based sensors can be placed in various locations throughout a mine to monitor different environmental factors such as temperature, humidity, air quality, and gas levels. The data collected can be transmitted in real-time to a centralized gateway for analysis and visualization.
- Predictive analytics: By using machine learning algorithms and historical data, a safety monitoring system can predict potential safety hazards before they occur. For example, if the system detects a rise in gas levels, it can predict the likelihood of an explosion and alert workers to evacuate the area.
- Geolocation tracking: LoRa-based sensors can be equipped with GPS technology to track the location of workers and equipment in real-time. This can be useful in case of an emergency, as it allows rescuers to quickly locate workers who may be trapped.
- Remote control and automation: LoRa-based sensors can be connected to machinery and equipment to allow for remote control and automation. This can help reduce the risk of accidents by removing the need for workers to manually operate heavy machinery in hazardous environments.

Circuit Diagram

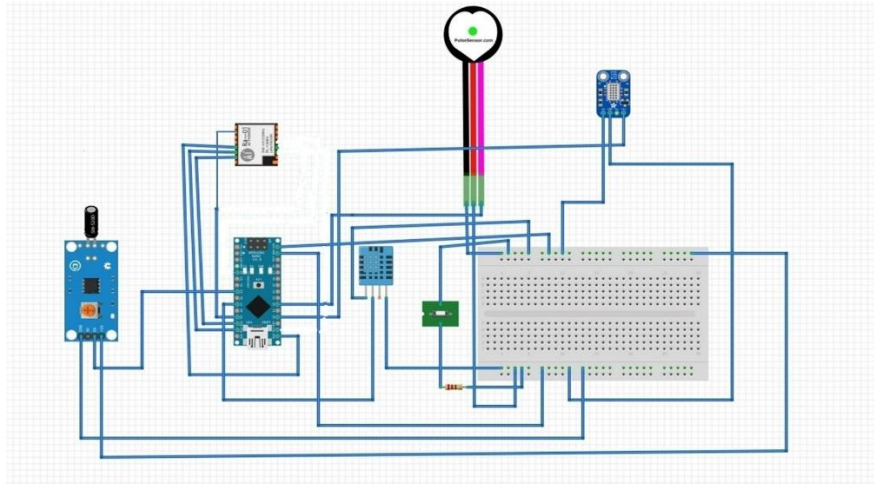


Fig.1.1 Transmitter Section

Fig.1.1 shows the circuit diagram of the transmitter section which is connected to the miner. A nano is used as controller which is responsible for taking input parameters from the connected components and transmit through LoRa. A LoRa is used for the long-range communication between a miner and control unit. It mainly consists of a few sensors like a pulse sensor, which is used to monitor the pulse of the miner. A tilt sensor is used to detect the vibrations occurring inside the mine. A temperature sensor usually measures the temperature and humidity across the miner's location. A gas sensor i.e. MQ2 used to detect the harmful gases present in the mine. A switch is used by a miner as a safe-guard to send the pulse (emergency indication) to the control unit.

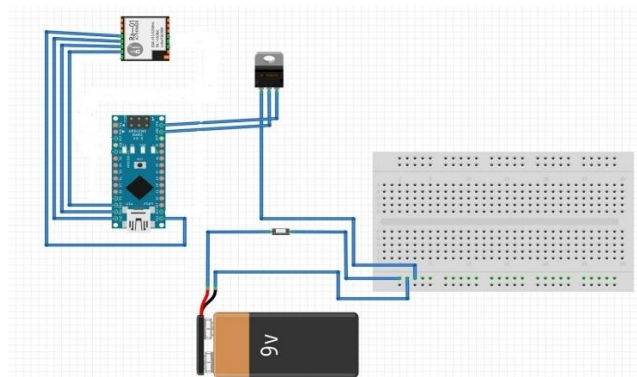


Fig.1.2 Repeater Section

Overall, a safety monitoring system for coal mining using LoRa can provide an advanced and reliable solution for improving safety in hazardous environments. By using real-time data monitoring, predictive analytics, geolocation tracking, remote control, and battery optimization, the system can help reduce the risk of accidents and improve the safety of workers in coal mines.

CHAPTER 2

LITERATURE SURVEY

2.1 INFERENCES FROM LITERATURE SURVEY

Coal is one of the most important fuel sources and is of paramount important to many industries which helps in generation of electricity, steel production, cement manufacturing and as a liquid fuel and many industrial applications. So, extracting the coal has become an important stint but there are many hazardous conditions in the extraction of coal like increase in temperature and humidity, release of harmful gases. These conditions create a dangerous environment for the mining workers to work in and pose a risk to their lives. As a means of reducing the intensity of problem caused by the working environment a creative and innovative methodology is required for the safety of mining workers. So, the few existing models are as below.

T. Porselvi, S. G. CS, J. B, P. K et al. (2021) presented work on IoT based Coal Mine Safety and Health Monitoring System using Lora WAN. The aim of this model is to observe the health parameters of the mineworkers and the toxic gas level in the coal mining environment. The data from the mine worker section is transmitted to the webpage through IoT using Lora WAN technology, establishing Wireless Communication (Lora WAN), and updating the data from the sensor to the Webpage.

So, in this system, two sections are considered one is to monitor the miner's health status and the other one is the total monitoring section. In the mine worker section, 2 smoke sensors are employed to monitor the different types of smoke level in the mine and the sensor measures values given to the microcontroller. If the smoke sensor values increase beyond the threshold range, then the microcontroller will give an alert to the person through buzzer and send the data to the monitoring section through the Lora WAN module. The received data is uploaded to the webpage through IOT.

In addition to that health parameters such as Heartbeat rate, Respiratory rate are monitored for the coal mine workers with the help of heartbeat and

respiratory sensors. Each sensor monitors the respective parameters and they are continuously sent to the IoT webpage using Lora WAN Technology. The sensors are programmed with a certain range of values, when the sensor outputs go above or below the buzzer is turned ON.[11]

P. Hazarika (2016) et al. presented work on Implementation of Smart Helmet for Coal Mine Workers provided this model presents implementation of safety helmet for coal mine workers. This helmet is equipped with methane and carbon monoxide gas sensor. This sensor senses the gas and the data is transmitted to the control room wirelessly, through a wireless module called X-Bee connected with the helmet. When the methane or carbon- monoxide gas concentration is beyond the critical level, controller in the control room triggers an alarm and keeps the plant and the workers safe by preventing an upcoming accident.

The smart safety helmet is one of most effective and useful technique in mining industries due to its excellent sensing ability, low cost, good and reliable signal transmission. Also, the system can be monitored in Lab view and in a portable mini monitor panel, which gives the system versatility. Lab-view monitoring is more accurate but is little expensive due to the expense of the software. On the other hand, hand-held portable monitoring device is very cheap and good for monitoring few routers.[12]

Suganya, R., & Gowtham (2021) presented work on Individual Health and Safety Monitoring of Workers in Deep Underground Mines Using IOT provided this model presents a strategy for investigating and guaranteeing wellbeing of the labourers in mines. It is carried out by using IOT to set up remote sensor organize. Different sensors such as Temperature, Heartbeat, CH₄ (Methane), CO₂ (Carbon dioxide), CO (Carbon monoxide) are utilized for estimating air quality boundaries. This system consists of two nodes one is Safety node and the other is Health node. These nodes are wearable nodes. Various sensors are connected to the Arduino and each sensor monitors the respective parameters and sent to the IoT using LoRa. This type of system can be used to improve safety in coal mining operations by detecting and alerting workers of potential hazards such as gas leaks, fires, and cave-ins. [13]

Poornima, Mrs & Sai, T. (2020) presented work on Coal mine monitoring system using Arduino and LoRa provided this aim of this model is a smart tracking machine for coal mineshafts, which goals at checking the coal mineshaft produce system. In this the IoT detects the uncertainty within the surroundings in beforehand using data evaluation and reviews the scenario to the involved authority and miners.[1] In this monitoring system various sensors (CO2 sensor, smoke sensor, methanesensor, DTH11 sensor) are connected to the Arduino which collects the statistics from them and transmit to the LoRa which is connected to the Arduino. The LoRa which is connected to the Node MCU enables to shop the statistics in cloud (Thing speak cloud).In order to check the readings, the mobile app (push bullet app) is connectedto cloud where all the results of the respective gadgets are visible on the app.[14]

U. Raza, P. Kulkarni and M. Sooriyabandara (2017) presented work on IOT Based Advanced Underground Coal Mine EnvironmentalDetection and Auto Alert system for Coal Mine Workers using Blynk Application provided the present work focuses on sensing environmental parameters such as temperature, Humidity, Gas from different locations in the mines and sends the alertto the mine control room who uses blynk application whenever there seems to be dangerous situation.

This system uses an IoT platform as a medium to transmit the data. Here all the sensors are together placed as a unit to an Arduino board and sent into the coal mineas a bot (Robot) which observes the respective parameters and sends the informationto the user using Blynk application. When any of the parameters reaches its peril, it alerts the user in the Blynk application.[1]

R. K. Kodali and S. Sahu (2018) presented work on IoT Based safety system for coal mines they developed model senses the environmental parameters from different locations in the mine and sends alert to the mine control room. This is a Publisher- Subscriber model (Separates the client that sends message and client that receivesmessage) based system. In this system the Node MCU acts like a publisher which publishes the sensor data to the Raspberry Pi, which is a MQTT Breaker (Message Queuing Telemetry Transport-used for data exchange between devices and server).

The data from the different Node MCU's located at different locations is automatically stored in Raspberry Pi. This is done by Node-Red Flows (Programming tool for wiring together hardware devices, API's and Online servers) which take the data received from the publishers and store them in a file. As the Pi receives sensor data from different location in mines whenever the values are exceeded it sends an alert to workers by means of alarm and to mine controlling center through an email.[15]

2.2 OPEN PROBLEMS IN EXISTING SYSTEM

From our Literature Survey we found that many systems were implemented using IoT where a Wi-Fi module is used to transmit the information. IoT devices aren't always included in the strategy for security and privacy. Security protocols with IoT devices can be difficult and cost is also another concern. The proposed system is a safety monitoring system which is embedded based and also we designed the system in such a way to increase the range of communication by cascading the Lora's.

CHAPTER 3

REQUIREMENTS ANALYSIS

3.1 RISK ANALYSIS OF THE PROJECT

To ensure the safety of coal mining workers, a safety monitoring system based on LoRa (Long Range) and risk analysis can be designed. LoRa technology can be used to transmit data over long distances while consuming little power, making it ideal for use in mining environments where connectivity is frequently limited.

Sensors can be installed in various locations throughout the mining site to monitor various parameters such as temperature, humidity, gas levels, and vibration. The data collected by these sensors can then be transmitted to a central server via LoRa technology.

A risk analysis algorithm can be used to analyze the data collected by the sensors and identify potential safety hazards. For example, if the temperature or humidity levels exceed certain thresholds, the system can alert workers to the potential danger and recommend appropriate safety measures. Similarly, if gas levels or vibrations reach dangerous levels, the system can send an alert to workers to immediately evacuate the area.

The system can also be integrated with wearable devices such as smartwatches or safety helmets, which can provide workers with real-time updates on their personal safety status. This can include information about their location within the mine, any potential hazards in their immediate vicinity, and the status of their equipment.

In conclusion, a safety monitoring system for coal miners that uses LoRa and risk analysis can provide a reliable and efficient way to monitor and manage safety hazards in mining environments. This system can help to prevent accidents and ensure worker safety in the coal mining industry by utilizing advanced technologies and real-time data analysis. To mitigate these risks, it is essential to develop a robust risk management plan that includes measures such as regular maintenance of equipment, staff training programs, and contingency plans for communication failures and equipment malfunctions.

3.2 HARDWARE AND SOFTWARE REQUIREMENTS

The system is designed using the hardware components and software programming. The following are the required hardware components

3.2.1 Hardware requirements

- Node MCU (ESP8266)
- Arduino Nano
- WIR-1186 LoRa RF module
- DHT11–Temperature and Humidity Sensor
- SW-420 Vibration Sensor Module
- Pulse Sensor
- Gas Sensor (MQ2)
- LM2596 DC-DC converter
- Power Supply Circuit (12V)
- Voltage Regulator
- Resistor (1kilo ohm)
- Helix Antenna
- I2C LCD (Liquid Crystal Display)
- Buzzer
- Jumper Wires
- PCB

3.2.1.1 NodeMCU (ESP8266)

NodeMCU is an open-source Lua based firmware and development board specially targeted for IoT-based Applications. fig 3.1 shows the hardware part of Nodemcu. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP- 12 module.

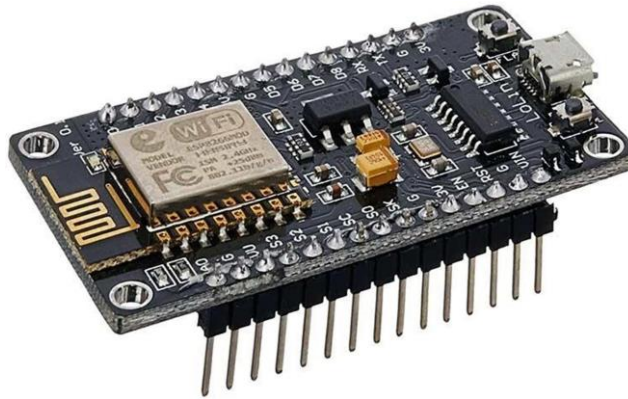


Fig.3.1 NodeMCU (ESP8266)



Modified to Arduino Nano due to insufficient pins

3.2.1.2 Arduino Nano

Arduino Nano is one type of microcontroller board, and it is designed by Arduino.cc. It can be built with a microcontroller like Atmega328. This microcontroller is also used in Arduino UNO. It is a small size board and also flexible with a wide variety of applications. Other Arduino boards mainly include Arduino Mega, Arduino Pro Mini, Arduino UNO, Arduino YUN, Arduino Lilypad, Arduino Leonardo, and Arduino Due. And other development boards are AVR Development Board, PIC Development Board, Raspberry Pi, Intel Edison, MSP430 Launchpad, and ESP32 board. The board features 14 digital input/output pins, 6 analog input pins, and a USB connection for programming and serial communication. It also has an onboard voltage regulator, which allows it to operate at different voltage levels, making it suitable for a wide range of projects.

This board has many functions and features like an Arduino Duemilanove board. However, this Nano board is different in packaging. Fig 3.2 shows the hardware part of Arduino board. It doesn't have any DC jack so that the power supply can be given using a small USB port otherwise straightly connected to the pins like VCC & GND. This board can be supplied with 6 to 20volts using a mini-USB port on the board.



Fig.3.2 Arduino Nano

Features

- ATmega328P Microcontroller is from 8-bit AVR family
- Operating voltage is 5V
- Input voltage (V_{in}) is 7V to 12V
- Input/Output Pins are 22
- Analog i/p pins are 6 from A0 to A5
- Digital pins are 14
- , & USART
- Power consumption is 19 mA
- I/O pins DC Current is 40 mA
- Flash memory is 32 KB
- SRAM is 2 KB
- EEPROM is 1 KB
- CLK speed is 16 MHz
- Size of the printed circuit board is 18 X 45mm
- Supports three communications like SPI, I²
- The Arduino Nano has 32KB of flash memory for storing code, 2KB of SRAM for variables, and 1KB of EEPROM for storing data.

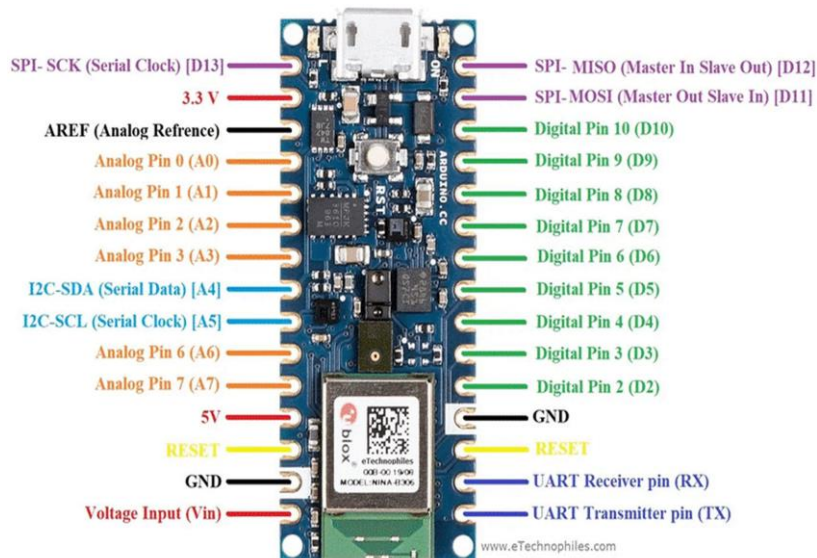


Fig.3.3 Arduino Nano pinout Diagram

Power Pin (Vin, 3.3V, 5V, GND): These pins are power pins fig 3.3 shows the pinout of Arduino nano.

- Vin is the input voltage of the board, and it is used when an external power source is used from 7V to 12V.
- 5V is the regulated power supply voltage of the nano board and it is used to give the supply to the board as well as components.
- 3.3V is the minimum voltage which is generated from the voltage regulator on the board.
- GND is the ground pin of the board

RST Pin (Reset): This pin is used to reset the microcontroller

Analog Pins (A0-A7): These pins are used to calculate the analog voltage of the board within the range of 0V to 5V

I/O Pins (Digital Pins from D0 – D13): These pins are used as an i/p otherwise o/p pins. 0V & 5V

Serial Pins (Tx, Rx): These pins are used to transmit & receive TTL serial data.

External Interrupts (2, 3): These pins are used to activate an interrupt.

PWM (3, 5, 6, 9, 11): These pins are used to provide 8-bit of PWM output.

SPI (10, 11, 12, & 13): These pins are used for supporting SPI

communication. **Inbuilt LED (13):** This pin is used to activate the LED.

IIC (A4, A5): These pins are used for supporting TWI communication.

AREF: This pin is used to give reference voltage to the input voltage

Arduino Nano Communication

The communication of an Arduino Nano board can be done using different sources like using an additional Arduino board, a computer, otherwise using microcontrollers. The microcontroller using in Nano board (ATmega328) offers serial communication (UART TTL). This can be accessible at digital pins like TX, and RX. The Arduino software comprises of a serial monitor to allow easy textual information to transmit and receive from the board.

The TX & RX LEDs on the Nano board will blink whenever information is being sent out through the FTDI & USB link in the direction of the computer. The library-like Software Serial allows serial communication on any of the digital pins on the board. The microcontroller also supports SPI & I2C (TWI) communication.

Arduino Nano Programming

Programming the Arduino Nano is a fun and rewarding experience for anyone interested in electronics and programming. The Arduino Nano uses the Arduino Integrated Development Environment (IDE), which is a software platform that allows you to write, compile, and upload code to the board. The programming language used is C++, which is a popular language for embedded systems and microcontrollers

The programming of an Arduino nano can be done using the Arduino software. Click the Tools option and select the nano board. Microcontroller ATmega328 over the Nano board comes with pre-programmed with a boot loader. This boot loader lets to upload new code without using an exterior hardware programmer. The communication of this can be done with the STK500 protocol. Here the boot loader can also be avoided & the microcontroller program can be done using the header of in-circuit serial programming or ICSP with an Arduino ISP. Table 3.1 shows the Arduino nano development board pinout configuration.

Table.3.1 Arduino Nano Development Board Pinout Configuration

Pin	Function	Description
A0	Analog input	Analog input 0
A1	Analog input	Analog input 1
A2	Analog input	Analog input 2
A3	Analog input	Analog input 3
A4	Analog input/SDA	Analog input 4 or I2C data
A5	Analog input/SCL	Analog input 5 or I2C clock
A6	Analog input	Analog input 6
A7	Analog input	Analog input 7
0	RX	Receive Serial Data
1	TX	Transmit Serial Data
2	Digital input/output	Digital input/output 2
3	Digital input/output	Digital input/output 3
4	Digital input/output	Digital input/output 4
5	Digital input/output	Digital input/output 5
6	Digital input/output	Digital input/output 6
7	Digital input/output	Digital input/output 7
8	Digital input/output	Digital input/output 8
9	Digital input/output	Digital input/output 9
10	Digital input/output	Digital input/output 10
11	Digital input/output	Digital input/output 11
12	Digital input/output	Digital input/output 12
13	Digital input/output	Digital input/output 13
GND	Power	Ground
Vin	Power	Input Voltage
5V	Power	Regulated 5V output
3.3V	Power	Regulated 3.3V output
RESET	Reset	Reset Input

3.2.1.3 WIR-1186 LoRa RF module

The WIR-1186 module is a low-power wireless communication solution that is ideal for Smart Grid, home automation, smart lighting, industrial sensor data acquisition and remote-control applications. This module integrates SPIRIT1/RF69, an extremely low-power sub-GHz transceiver, an MCU for wireless network control and hardware interface, a PCB antenna and matching circuitry. Right out-of-the-box this module supports simple point-to-multipoint serial communication over-the-air. It has a small 24mm x 36mm form-factor for easy integration.

The WIR-1186 LoRa RF module is a wireless communication module that uses the LoRa modulation technique to provide long-range, low-power communication capabilities. Fig 3.4 shows the hardware module The WIR-1186 of. The module is based on the SX1276 chip from Semtech, which is a highly integrated RF transceiver that operates in the 868MHz or 915MHz frequency band.

This module allows OEMs to easily add wireless sub-GHz capability to their electronic devices. A simple cable replacement model allows the module to be used similarly to a standard serial interface. Full CE compliance and FCC compliance reduces time to market.

The WIR-1186 module is based on the Semtech SX1276 transceiver chip, which provides a high level of sensitivity (-148dBm) and output power (up to +20dBm) for long-range communication. It also features a range of modulation options (including LoRa, FSK, GFSK, and OOK) to optimize performance for different application scenarios.

In addition to its hardware features, the WIR-1186 module is also equipped with a firmware stack that supports LoRaWAN (Low Power Wide Area Network) connectivity, enabling it to communicate with a range of LoRaWAN gateway devices and network servers. This makes it easy to integrate the module into existing IoT infrastructure and platforms. The module also supports various sleep modes, which helps to conserve battery power in battery-powered applications. The WIR-1186 is a compact, low-power, long-range wireless communication module based on the LoRa technology.

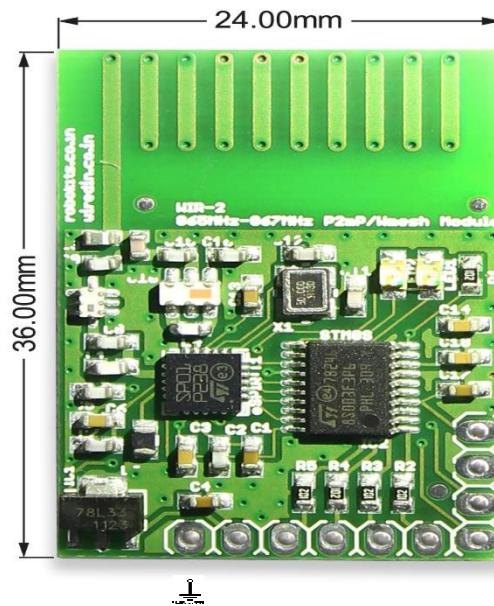


Fig.3.4 WIR-1186 LoRa RF Module

The WIR-1186 modules support data-hopping, listen-before-talk with random back-off algorithm, end-to-end acknowledgement system, node addressing, network addressing and packet CRC. Nodes can be configured to enable hopping of data to increase the range of the communication link. Table 3.2 shows the pin description of WIR-1186 .The destination node address is configurable to setup an acknowledgement based point-to-point communication. Without setting the destination data will be broadcasted to all nodes on the same network address.

The module uses a simple serial interface to communicate with microcontrollers or other devices, allowing for easy integration into existing systems. It supports multiple modulation schemes, including LoRa, FSK, GFSK, and OOK, providing flexibility in designing the communication link. In terms of specifications, the WIR-1186 has a range of up to 15km in rural areas and up to 5km in urban environments. It supports data rates of up to 300kbps and has a low power consumption of 12.5mA in transmit mode and 16mA in receive mode.

Overall, the WIR-1186 LoRa RF module is a versatile and reliable wireless communication module that provides long-range, low-power communication capabilities for a wide range of applications. Its small size and low power consumption make it an ideal choice for remote monitoring and other battery-powered applications.

Table.3.2 Pin Description of WIR-1186

	Pin Name	Description
1	GND	Ground pin of the Module
2	VCC	3.2V – 3.6V supply voltage
3	PROG	Enter configure mode (active-low)
4	UART-TX	Module Serial Data input
5	UART-RX	Module Serial Data output
6	CTS	Clear to send output to device

Features

- RF center frequency of 865MHz to 869MHz (can be modified for other bands)
- Small 24mm x 36mmx3mm form factor. Can fit into almost anything.
- Standard UART interface with hardware flow-control (Clear-to-Send CTS)
- Easy to integrate into current devices that support RS-485, RS-232, RS-422 or 3.3V TTL serial data
- Compatible to 3.3V power-supply and interface
- Integrated efficient PCB antenna
- Robust network protocol for point-to-point and data hopping communication
- Listen-before-talk and random back-off algorithm
- 16bit node address and 16bit network address
- Acknowledgement based point-to-point communication with data hopping over repeaters
- Settable channels, baud-rate, air-data rate and RF transmit power
- Configurable parameters, signal-strength limit, ack timeout, network and point address
- Transparent AES Encryption and Decryption on all wirelessly transmitted data

3.2.1.4 DHT11–Temperature and Humidity Sensor

The DHT11 is a commonly used Temperature and humidity sensor that comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data.

Fig 3.5 hardware module of DHT11–Temperature and Humidity Sensor.

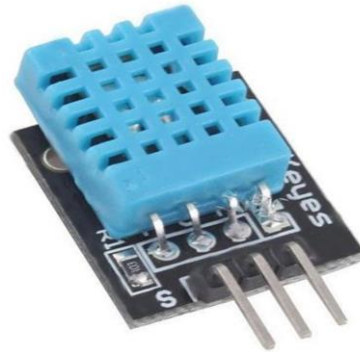


Fig.3.5 DHT11–Temperature and Humidity Sensor

DHT11 Specifications

- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: 0°C to 50°C
- Humidity Range: 20% to 90%

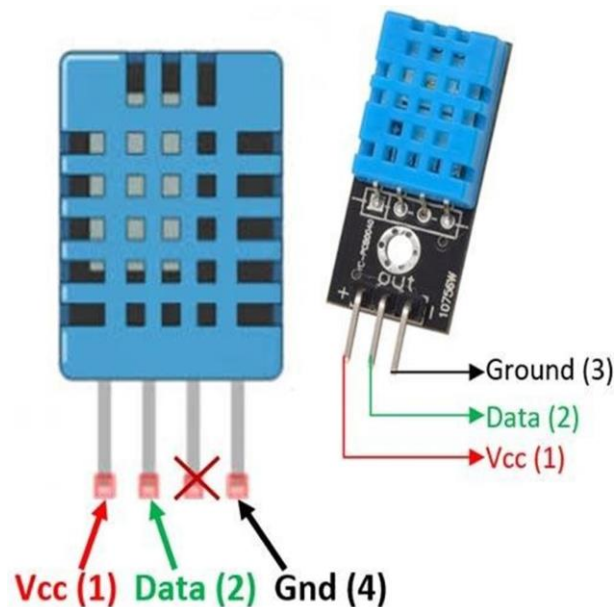


Fig.3.6 DHT11 Sensor Pinout

Table.3.3 DTH11 Pinout Identification and Configuration

No:	Pin Name	Description
For DHT11 Sensor		
1	VCC	Power supply 3.5V to 5.5V
2	Data	Outputs both Temperature and Humidity through serial Data
3	NC	No Connection and hence not used
4	Ground	Connected to the ground of the circuit
For DHT11 Sensor module		
1	VCC	Power supply 3.5V to 5.5V
2	Data	Outputs both Temperature and Humidity through serial Data
3	Ground	Connected to the ground of the circuit

Difference Between DTH11 Sensor and DTH11 Module

The DHT11 sensor can either be purchased as a sensor or as a module. Either way, the performance of the sensor is same. Table 3.3 DTH11 Pinout Identification and Configuration. The sensor will come as a 4-pin package out of which only three pins will be used whereas the module will come with three

pins as shown above. The only difference between the sensor and module is that the module will have a filtering capacitor and pull-up resistor inbuilt, and for the sensor, you have to use them externally if required.

3.2.1.5 SW-420 Vibration Sensor

A vibration sensor is a device that measures the amount and frequency of vibration in a given system, machine, or piece of equipment. Fig 3.7 Pinout of SW-420 Vibration sensor Those measurements can be used to detect imbalances or other issues in the asset and predict future breakdowns. Table.3.4 shows the pin description of SW-420 vibration sensor

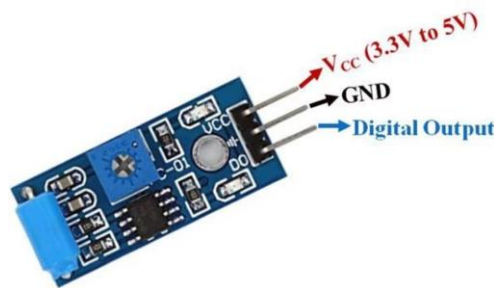


Fig.3.7 Pinout of SW-420 Vibration sensor

Table.3.4 Pin Description of SW-420 Vibration Sensor

Pin Name	Description
VCC	The Vcc pin powers the module, typically with +5V
GND	Power Supply Ground
DO	Digital Out Pin for Digital Output.

Vibration Sensor Module Features & Specifications

- Operating Voltage: 3.3V to 5V DC
- Operating Current: 15mA
- Using SW-420 normally closed type vibration sensor
- LEDs indicating output and power
- LM393 based design
- Easy to use with Microcontrollers or even with normal Digital/Analog IC

➤ With bolt holes for easy installation, Small, cheap and easily available

Brief about SW-420 Vibration Sensor/Motion Sensor Module

Fig.3.8 SW-420 Vibration Sensor shows the hardware module. This Vibration Sensor Module consists of an SW-420 Vibration Sensor, resistors, capacitor, potentiometer, comparator LM393 IC, Power, and status LED in an integrated circuit. It is useful for a variety of shocks triggering, theft alarm, smart car, an earthquake alarm etc.

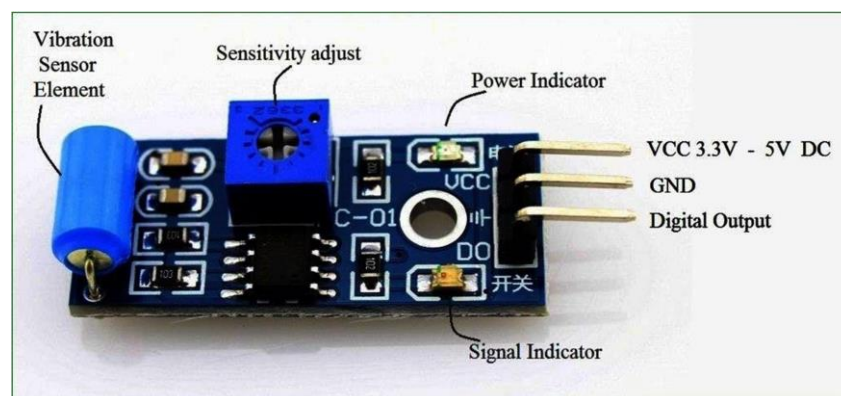


Fig.3.8 SW-420 Vibration Sensor

3.2.1.6 Pulse Sensor

A plug-and-play sensor that is used to detect the heart rate data is known as a pulse sensor. This sensor is used by athletes, students, mobile & game developers, etc. This sensor clips on an earlobe or a fingertip by connecting right to an Arduino board through jumper cables. In real-time, the pulse rate can be monitored through an open-source monitoring app. The pulse sensor typically consists of a small sensor that is placed on the skin, usually on the fingertip or earlobe. The sensor measures the amount of blood flowing through the blood vessels and detects the changes in blood volume that occur with each heartbeat. These changes are then converted into electrical signals, which can be used to determine the heart rate. Overall, pulse sensors are a valuable tool for monitoring heart health and physical activity, and can help people to stay healthy and active.

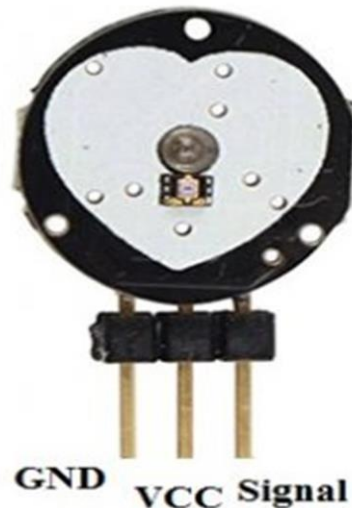


Fig.3.9 Pulse Sensor

Pin Configuration

The pulse sensor pin configuration includes three pins which are discussed below.

- **Pin1 (Ground):** This is a black color wire, used to connect to the GND terminal of the system
- **Pin2 (Vcc):** This is a red color wire, used to connect to +3.3V/+5V voltage supply
- **Pin3 (Signal):** This is a purple color wire, used to connect the output signal which is pulsating.

Features & Specifications

The features of the pulse sensor include the following.

- This is a heart rate/biometric pulse rate detecting sensor
- This is a plug & play type sensor
- The operating voltage of this sensor is +5V/+3.3V
- Consumption of current is 4mA
- Length is 0.625"
- Width is 0.125"
- Integral Amplification
- Circuit for cancellation of noise

The specifications of the pulse sensor include the following.

- The maximum current is 100mA

- Heartbeat deduction output LED
- VCC is +5v DC through high-quality regulation
- Light source – 660nm super Red LED

3.2.1.7 MQ2 Gas Sensor



Fig.3.10 MQ2 Gas Sensor

Fig.3.10 shows the MQ2 Gas Sensor is one of the commonly used gas sensors in MQ sensor series. It is a MetalOxide Semiconductor (MOS) type Gas Sensor also known as Chemiresistors as the detection is based upon change of resistance of the sensing material when the Gas comes in contact with the material. Fig.3.11 shows the MQ2 Gas Sensor pinout Diagram.



Fig.3.11 MQ2 Gas Sensor pinout Diagram

VCC: It supplies power for the module. You can connect it to 5V output from your Arduino.

GND: It is the Ground Pin and needs to be connected to GND pin on the Arduino.

D0: It provides a digital representation of the presence of combustible gases.

A0: It provides analog output voltage in proportional to the concentration of smoke/gas

3.2.1.8 LM2596 DC-DC Converter

DC-DC Buck Converter Step Down Module LM2596 Power Supply is a step-down(buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation. Fig.3.12 shows the LM2596 DC-DC converter. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version. The LM2596 series operates at a switching frequency of 150kHz, thus allowing smaller sized filter components than what would be required with lower frequency switching regulators.

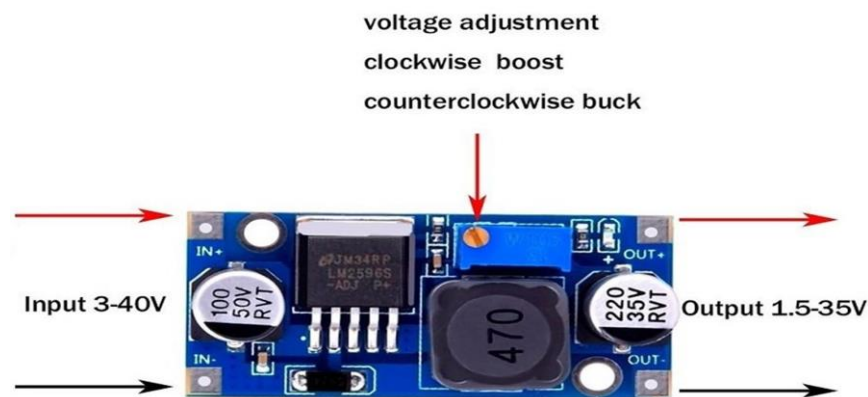


Fig.3.12 LM2596 DC-DC Converter

This is an LM2596 DC-DC buck converter step-down power module with the high-precision potentiometer, capable of driving a load up to 3A with high efficiency, which can work with Freeduino UNO, other mainboards, and basic modules. When the output current keeps greater than 2.5A (or output power greater than 10W), please add a heat sink to it. This device is internally compensated to minimize the number of external components to simplify the power supply design.

Since LM2596 converter is a switch-mode power supply, its efficiency is significantly higher in comparison with popular three-terminal linear regulators, especially with higher input voltages. Table.3.5 shows the specifications of LM2596 DC-DC converter. The LM2596 operates at a switching frequency of 150 kHz thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators. The LM2596 is a DC-DC step-down converter that is commonly used in electronic circuits to efficiently regulate and convert a higher DC voltage to a lower DC voltage.

Features:

- Input voltage:3-40V
- Output voltage:1.5-35V(Adjustable)
- Output current: Rated current is 2A, maximum 3A (Additional heatsink is required)
- Module Properties: non-isolated constant voltage module
- Rectification: non-synchronous rectification

Table.3.5 Specifications of LM2596 DC-DC Converter

Input Voltage	3-40V
Output Voltage	1.5-35V(Adjustable)
Output Current	Rated Current:2A, Maximum Current:3A
Switching Frequency	150KHZ
Operating Temperature	Industrial Grade (-40 to +85)
Conversion Efficiency	92%
Load Regulation	±0.5%
Voltage Regulation	±0.5%
Dynamic Response Speed	5% 200uS

3.2.1.9 Power Supply Circuit (12V)

This 12V 1A power supply is mainly used in, chargers, microcontroller, portable amplifiers, audio-video players, Bluetooth/Wi-Fi modules, DC motors, led light circuits. Fig.3.13 shows the power supply circuit. Despite being small in size this power supply work effectively. The input voltage of this supply is 220VAC and output is 12V DC. This supply can provide up to 1A current. But we use a DC to DC converter which in turn to provide 12v of supply to 5v of input supply as per

the power requirements of all 5v modules like McroCs, LoRa , Sensors etc. Here we used this supply to MCs and sensors.



Fig.3.13 Power Supply Circuit

3.12.1.10 Voltage Regulator (LM7805)

7805 is a three terminal linear voltage regulator IC with a fixed output voltage of 5V which is useful in a wide range of applications. Fig.3.14 shows the LM7805 Voltage Regulator. Currently, the 7805 Voltage Regulator IC is manufactured by Texas Instruments, ON Semiconductor, STMicroelectronics, Diodes incorporated, Infineon Technologies, etc.

The equivalent ICs of this voltage regulator are IC LM7809, IC LM7806, IC LM317, IC LM7905, IC XC6206P332MR & IC LM117V33.

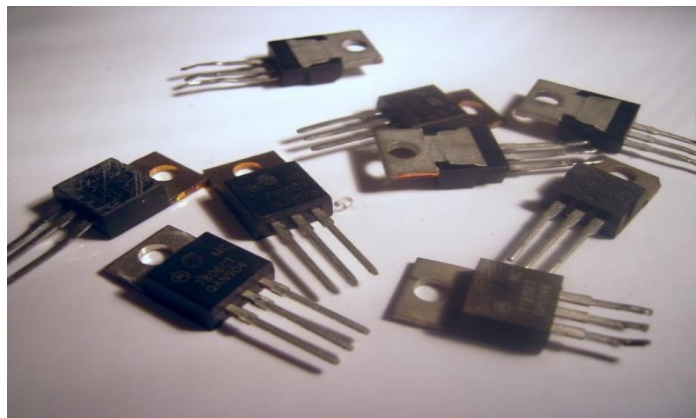


Fig.3.14 LM7805 Voltage Regulator

- Pin1 (Input): This is an input pin, where a positive unregulated voltage can be given like an input toward this pin.
- Pin2 (Ground): This is the GND pin where this pin is common to both input & output.

- Pin3 (Output): This is the output pin where the 5V of regulated voltage can be taken at this pin.

Specifications

- Operating Voltage: 5V
- Load Resistance: 20K Ω
- Heater Resistance: 33 $\Omega \pm 5\%$
- Heating Consumption: <800mw
- Sensing Resistance: 10 K Ω – 60 K Ω
- Concentration Scope: 200 – 10000ppm
- Preheat Time: Over 24 hours

3.2.1.11 Resistor (1 kilo ohm)

Fig.3.15 shows the Resistor is a passive two-terminal electrical component that implements electrical resistance as circuit element. Resistors act to reduce current flow, and at the same time act to lower voltage levels within the circuit. Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various compounds and forms. Resistors are also implemented within integrated circuits.

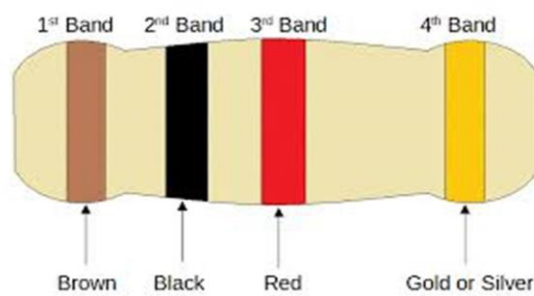


Fig.3.15 Resistor

3.2.1.12 Helix Antenna 433Mhz:

Fig 3.16 shows the Helix antenna 433Mhz. A helical antenna is an antenna consisting of one or more conducting wires wound in the form of a helix. A helical antenna made of one helical wire; it has been widely used in telecommunication to communicate. One of the main reasons to use a helix antenna is its low cost and compact size. A

helix antenna is a type of antenna with a three-dimensional structure that is shaped like a helix. This design allows for circularly polarized radiation, making it a popular choice for various radio communication applications. The 433MHz helix antenna is specifically designed to operate at a frequency of 433 MHz, which is commonly used for wireless communication applications such as remote controls, wireless sensors, and other low-power devices. The design of the helix antenna consists of a helical wire wound around a central cylindrical core. The number of turns in the helix, the diameter of the wire, and the spacing between turns all affect the performance of the antenna. The helix antenna has a high gain and a narrow beamwidth, making it suitable for point-to-point communication applications. The 433MHz helix antenna can be made from various materials, including copper wire or tubing, and can be designed for various polarizations such as circular, right-hand or left-hand.

Application: Sub GHz, Smart Meters.



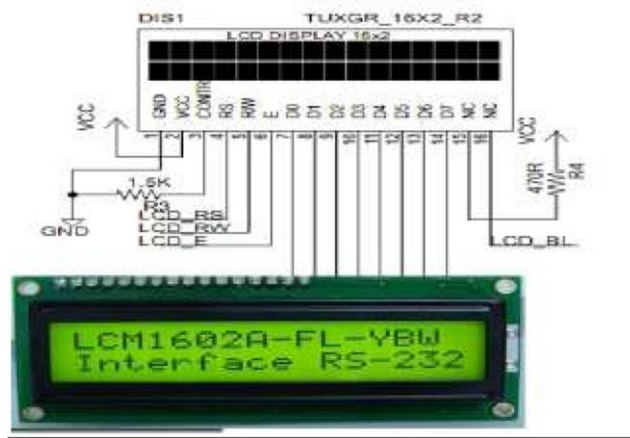
Fig 3.16 Helix antenna 433Mhz

Features:

- Compact Size
- Low Cost
- Right Angle version available on request
- Tin and Nickel plated for corrosion-free
- Antennas with a rubber sleeve to protect from spark

3.2.1.12 LCD (Liquid Crystal Display)

Fig 3.17 shows the Liquid Crystal Display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. Each pixel consists of a column of liquid crystal molecules suspended between two transparent electrodes, and two polarizing filters, the axes of polarity of which are perpendicular to each other. Without the liquid crystals between them, light passing through one would be blocked by the other. The liquid crystal twists the polarization of light entering one filter to allow it to pass through



the other.

Fig 3.17 Liquid Crystal Display

A program must interact with the outside world using input and output devices that communicate directly with a human being. One of the most common devices attached to an controller is an LCD display. Some of the most common LCDs connected to the controllers are 16X1, 16x2 and 20x2 displays. This means 16 characters per line by 1 line 16 characters per line by 2 lines and 20 characters per line by 2 lines, respectively. Many microcontroller devices use 'smart LCD' displays to output visual information. LCD displays designed around LCD NT-C1611 module, are inexpensive, easy to use, and it is even possible to produce a readout using the 5X7 dots plus cursor of the display. They have a standard ASCII set of characters and mathematical symbols. For an 8-bit data bus, the display requires a +5V supply plus 10 I/O lines (RS RW D7 D6 D5 D4 D3 D2 D1 D0). For a 4-bit data bus it only requires the supply lines plus 6 extra lines (RS RW D7 D6 D5 D4).

When the LCD display is not enabled, data lines are tri-state and they do not interfere with the operation of the microcontroller.

I2C Serial Interface Adapter Module for LCD

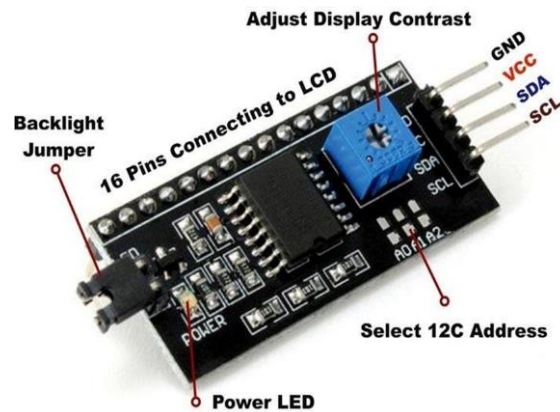


Fig.3.18 I2C Serial Interface Adapter Module I2C Serial Interface Adapter Module Pinout

Due to limited pin resources in a microcontroller/microprocessor, controlling an LCD panel could be tedious. Fig.3.18 shows the I2C Serial Interface Adapter Module I2C Serial Interface Adapter Module Pinout. Serial to Parallel adapters such as the I2C serial interface adapter module with PCF8574 chip makes the work easy with just two pins. Table.3.6 shows the Pin Configuration of I2C Serial Interface Adapter Module. The serial interface adapter can be connected to a 16x2 LCD and provides two signal output pins (SDA and SCL) which can be used to communicate with an MCU/MPU.

Features and Specifications of I2C Serial Interface Adapter Module

This section mentions some of the features and specifications of the I2C Serial Interface Adapter Module.

- Operating Voltage: 5V DC
- I2C control using PCF8574
- Can have 8 modules on a single I2C bus
- I2C Address: 0X20~0X27 (the original address is 0X20, you can change it yourself via the onboard jumper pins)

Table.3.6 Pin Configuration of I2C Serial Interface Adapter Module

Pin Name	Pin Type	Pin Description
GND	Power	Ground
VCC	Power	Voltage Input
SDA	I2C Data	Serial Data
SCL	I2C Clock	Serial Clock
A0	Jumper	I2C Address Selection 1
A1	Jumper	I2C Address Selection 2
A2	Jumper	I2C Address Selection 3
Backlight	Jumper	Control Backlight of panel

Table 3.7 Connecting I2C Serial Interface Adapter Module to an MCU/MPU The module has multiple pins onboard for communication with the MCU/MPU via the I2C protocol. The table below shows the pin name, type, and their functions.

Table 3.7 Connecting I2C Serial Interface Adapter Module to an MCU/MPU

A0	A1	A2	Address
Open	Open	Open	0x27
Jumper	Open	Open	0x26
Open	Jumper	Open	0x25
Jumper	Jumper	Open	0x24
Open	Open	Jumper	0x23
Jumper	Open	Jumper	0x22
Open	Jumper	Jumper	0x21
Jumper	Jumper	Jumper	0x20

The I2C serial adapter can be connected to 16x2 or 20x4 LCD displays via breakout pins. Fig.3.19 shows the Connecting I2C Serial Interface Adapter Module to an MCU/MPU. Once it fits perfectly onto the LCD, we can connect the module to any MCU/MPU using I2C protocol pins.

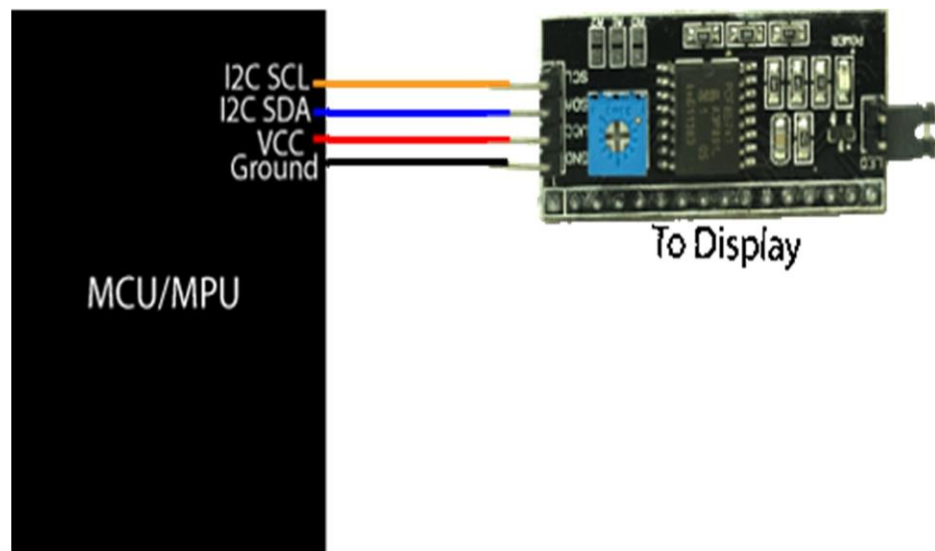


Fig.3.19 Connecting I2C Serial Interface Adapter Module to an MCU/MPU

The power points VCC and GND can be connected to the 5V and the ground terminal of the MCU/MPU, respectively. Also, connect the SDA, SCL pins of the module to the MCU/MPU I2C pins respectively to send the data.

Alternatives for I2C Serial Interface Adapter Module

PCF8574T, MCP23017

Applications of I2C Serial Interface Adapter Module

Here are some of the applications of the I2C Serial Interface Adapter Module.

- Serial to parallel data adapter
- Robots
- LCD Displays

2D Model of I2C Serial Interface Adapter Module

Below is the 2D model of the I2C Serial Interface Adapter Module along with its dimensions in millimeters. Fig.3.20 shows the 2-D model I2C Serial interface Adapter Module. The following information can be used to design custom footprints of the module for PCB designing and CAD modelling.

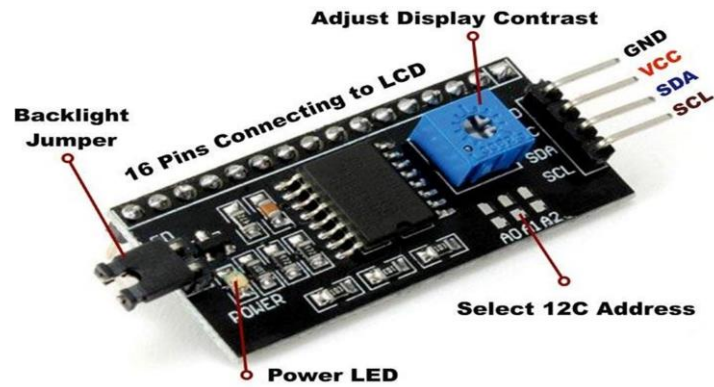


Fig.3.20 2-D model I2C Serial interface Adapter Module

3.2.1.13 Switch

Fig.3.21 shows the Switch or button (on an electrical appliance, etc.) which has an 'on' position and an 'off' position.



Fig.3.21 Switch

3.2.1.14 Buzzer

Fig.3.22 shows the Buzzer An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren. Buzzers are commonly used as alarms, in electronic games, and as indicators in electronic devices to signal various events or conditions. They can be found in a wide range of devices, from doorbells to car horns to industrial machinery.



Fig.3.22 Buzzer

Specifications

The specifications of the buzzer include the following.

- Color is black
- The frequency range is 3,300Hz
- Operating Temperature ranges from – 20° C to +60°C
- Operating voltage ranges from 3V to 24V DC
- The sound pressure level is 85dBA or 10cm
- The supply current is below 15mA

3.2.1.15 Jumper Wires

An electrical connector, is an electro-mechanical device used to join electrical terminations and create an electrical circuit. Electrical connectors consist of plugs (male-ended) and jacks (female-ended). The connection may be temporary, as for portable equipment, require a tool for assembly and removal.



Fig.3.23 Jumper Wires

electrical joint between two wires or devices. An adapter can be used to effectively bring together dissimilar connectors. Hundreds of types of electrical connectors are manufactured for power, signal and control applications. Connectors may join two lengths of flexible copper wire or cable, or connect a wire or cable to an electrical

terminal. In computing, an electrical connector can also be known as a physical interface (compare physical layer in OSI model of networking).

3.2.1.15 PCB



Fig.3.24 Printed Circuit Board

PCB or Printed Circuit Board is the traditional name for the bare board of which you supply us with the layout data and which you use to mount your components on once we have delivered it to you.

Fig.3.24 shows the Printed Circuit Board A printed circuit board, or PCB, is used to mechanically support and electrically connect electronic components using conductive pathways, tracks or signal traces etched from copper sheets laminated onto a non-conductive substrate.

When the board has only copper tracks and features, and no circuit elements such as capacitors, resistors or active devices have been manufactured into the actual substrate of the board, it is more correctly referred to as printed wiring board (PWB) or etched wiring board.

Use of the term PWB or printed wiring board although more accurate and distinct from what would be known as a true printed circuit board, has generally fallen by the wayside for many people as the distinction between circuit and wiring has become blurred.

Today printed wiring (circuit) boards are used in virtually all but the simplest commercially produced electronic devices, and allow fully automated assembly processes that were not possible or practical in earlier era tag type circuit

assembly processes.

A PCB populated with electronic components is called a printed circuit assembly (PCA), printed circuit board assembly or PCB Assembly (PCBA). In informal use the term “PCB” is used both for bare and assembled boards, the context clarifying the meaning

The IPC preferred term for populated boards is CCA, circuit card assembly. This does not apply to backplanes; assembled backplanes are called backplane assemblies by the IPC.

3.2.2 software requirements:

Arduino Ide:

Fig 3.25 shows the Arduino IDE The Arduino Integrated Development Environment (IDE) is a software application used for writing, compiling, and uploading code to Arduino boards. Here are some specifications and requirements for the Arduino IDE:

Operating Systems:

- Windows (7 or later)
- Mac OS X (10.10 Yosemite or later)
- Linux 32-bit (x86) or 64-bit (x86_64)

Programming Languages:

C/C++ (using the Arduino programming language and the Wiring libraries)

Board Compatibility:

Arduino Uno, Mega, Nano, Micro, Leonardo, Due, etc.
Other boards that are compatible with the Arduino software

Hardware Requirements:

USB cable (Type A/B) to connect the board to your computer

Internet connection (for downloading the software and updates)

Overall, the Arduino IDE is a flexible and easy-to-use software tool that allows users to write, compile, and upload code to a wide range of Arduino-compatible boards.

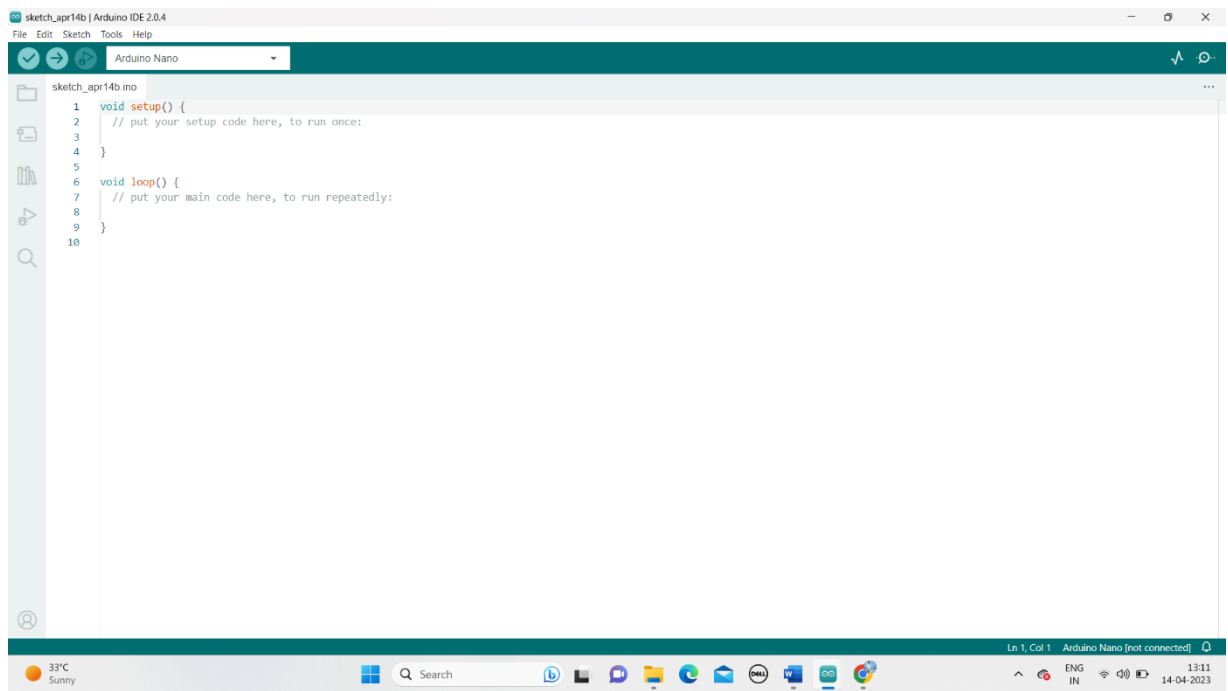


Fig 3.25 Arduino IDE

Features:

- Syntax highlighting
- Automatic code indentation
- Code completion/suggestions
- Integrated serial monitor
- Built-in libraries for common tasks
- Integrated upload tool for programming the board
- Support for third-party libraries and tools

CHAPTER 4

DESCRIPTION OF PROPOSED MODEL

The proposed model for a safety monitoring system for coal mining workers using LoRa would consist of a network of wireless sensors and a central monitoring station.

4.1 SELECTED METHODOLOGY OR PROCESS MODEL

To Design the Safety Monitoring of Mining Workers Using LoRa- Arduino Nano, WIR-1186 LoRa RF module, Pulse Sensor, Gas Sensor, Vibration Sensor, DHT11 Sensor, Switch, LCD, Buzzer, Voltage Regulator, AC- DC Converter, DC- DC Converter and Helix Antenna are required.

The system consists of three sections transmitter section, repeater section, and receiver section. In the transmitter section, all the sensors are connected to the Arduino and the information is transmitted from Arduino to Lora 1. Further, the information is transmitted to the Lora 2 present in the repeater section and finally, all the information is transmitted to the Lora 3 of the receiver section, and sensed values are displayed on the LCD.

4.2 ARCHITECTURE OR OVERALL DESIGN OF PROPOSED MODEL

The architecture of proposed system - Arduino Nano, WIR-1186 LoRa RF module, Pulse Sensor, Gas Sensor, Vibration Sensor, DHT11 Sensor, Switch, LCD, Buzzer, Voltage Regulator, AC- DC Converter, DC- DC Converter and Helix Antenna are required.

Fig 4.1 shows the System architecture of A Safety Monitoring System for Coal Mining Workers using LoRa The architecture consists of three sections transmitter section, repeater section, and receiver section. The sensors collect the data from the victim and sends the data to microcontroller and the received data send to LoRa 1 (transmitter section) and data sends to another microcontroller and to LoRa 2(repeater section) and sends to another microcontroller and LoRa 3(receiver section). And the received data displayed on LCD. The architecture of the safety monitoring system would be designed to ensure reliability, scalability, and security. The LoRaWAN network would be designed to cover the entire area of the mining site and would be capable of handling a large number of wireless sensors. The

wireless sensors would be designed to be rugged and durable, capable of withstanding the harsh environment of a coal mine. The central monitoring station would be designed to process data in real-time and to detect any potential safety hazards quickly, ensuring the safety of the coal mining workers.

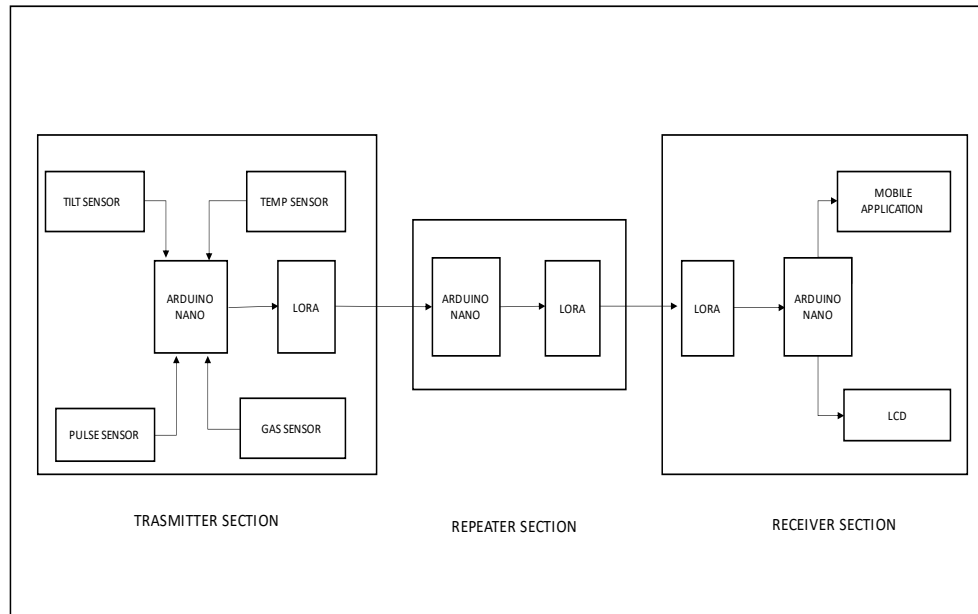


Fig 4.1 System architecture of A Safety Monitoring System for Coal Mining Workers using LoRa

4.3 DESCRIPTION OF SOFTWARE FOR IMPLEMENTATION AND TESTING PLAN OF THE PROPOSED SYSTEM

The Arduino Integrated Development Environment or Arduino Software (IDE) contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension (.ino). The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor. The development of electronics is now easier thanks to Arduino software (IDE), and Arduino boards (hardware). This set help to build digital and interactive devices with the help of other components.

The Arduino software (IDE) is an open-source software, which is used to programme the Arduino boards, and is an integrated development environment, developed by arduino.cc. Allow to write and upload code to Arduino boards. And it consists of many libraries and a set of examples of mini projects. Arduino software (IDE) is compatible with different operating systems (Windows, Linux, Mac OS X), and supports the programming languages (C/C++) The Arduino software is easy to use for beginners, or advanced users. It uses to get started with electronics programming and robotics, and build interactive prototypes. So, Arduino software is a tool to develop new things. and create new electronic projects, by Anyone (children, hobbyists, engineers, programmers, ... etc). To establish a serial communication between the Arduino Nano and the PC, you can use the Serial library in the Arduino IDE. The Serial library provides a set of functions to send and receive data through the serial port. Once the Arduino Nano is connected to the PC, the PC will automatically detect the board and install the necessary drivers. The board will appear as a new COM port in the Arduino Integrated Development Environment (IDE) or any other serial communication software.

- Connect your Arduino board into your computer by using the USB type a to bcable.

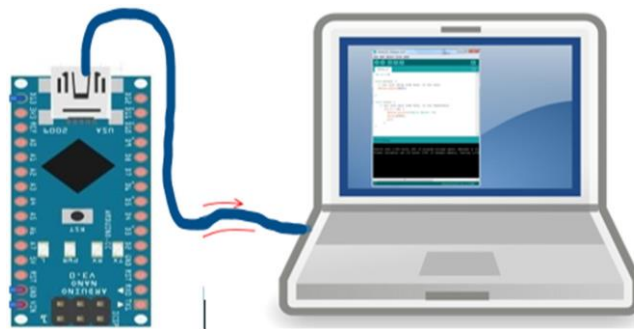


Fig.4.2 Connection between Arduino Nano and PC

- Open the Arduino IDE and go to Tools > Board > then select the Arduino Nano.

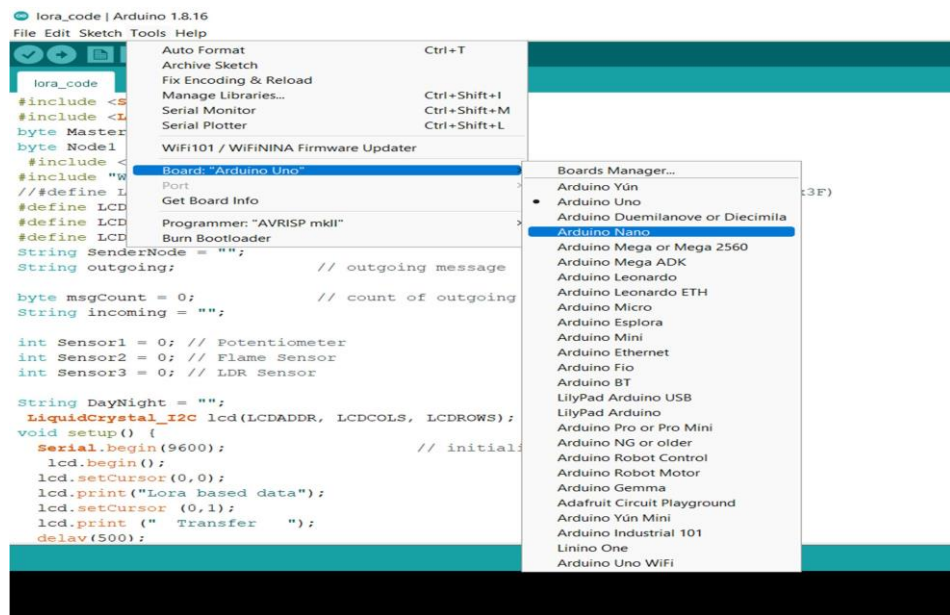


Fig.4.3 Selecting the board on Arduino IDE

- Now Open the Arduino IDE and go to Tools > port > then select the COM8(Arduino Nano).

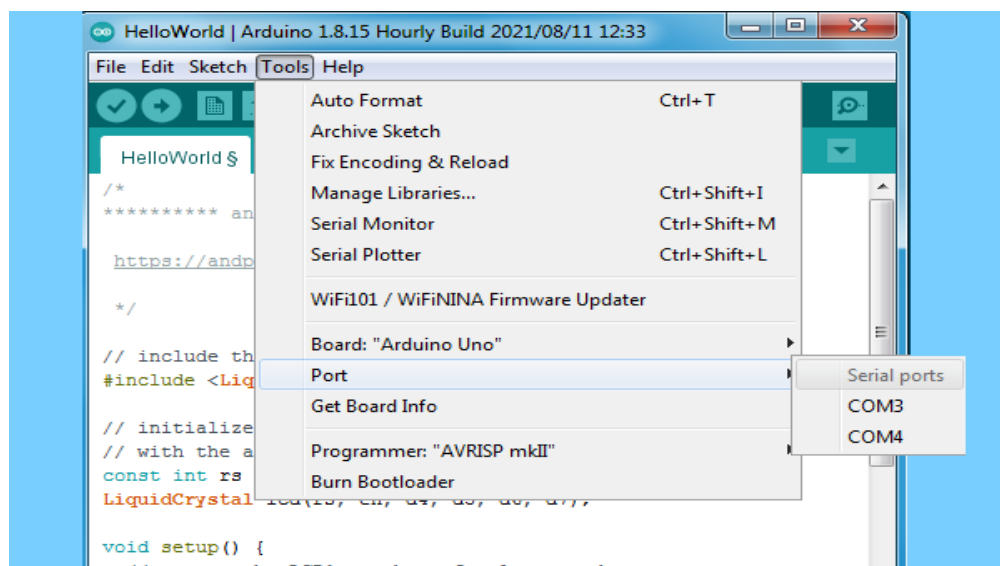


Fig.4.4 Selecting the port on Arduino IDE

- Now, write program on Arduino IDE.

Step 3: Testing

- After the Arduino IDE finishes the programming, you can now test the project. Place the sensor in water this should activate the buzzer, LED should turn ON and gate should be opened automatically.
- Now remove the sensor from water LED and buzzer should get turned off and also the dam gate should be closed automatically.
- If nothing is working redo the above steps and make sure the steps are followed correctly.

4.4 PROJECT MANAGEMENT PLAN

The safety monitoring system for coal mining workers using LoRa is a critical project that requires effective project management to ensure its success. This project management plan outlines the approach, roles, responsibilities, and timeline for the project

The first thing we looked for a which communication device is better for transmission data for a long range and at very fast phase. Among many options we have choosen LoRa as our communication device for this project.

Next we are looking for which microcontroller which is more reliable and cheap and which is best suitable for processing all data which coming from the sensor and we choose Arduino nano as our microcontroller.

Since in our project we are monitoring the mining worker we are measuring temperature and humidity levels using DHT11 and surrounding vibration using SW-421vibration sensor, pulse rate using pulse sensor and gases using MQ2 has sensor.

In our project we have three sections transmission section, repeater section and receiver section. We have made connection to each section and tested each one individually whether communication is established or not.

In sensors also we have tested each sensor seperately and integrated all the sensor and completed the communication setup.

At last we have done a live demo to check whether our project is successfully working or not and it worked our project is effectively working.

4.5 FINANCIAL REPORT ON ESTIMATED COSTING

Component name	Price
Arduino Nano	1410
WIR-1186 LoRa RF module	900
DHT11–Temperature and Humidity Sensor	210
SW-420 Vibration Sensor Module	105
Pulse Sensor	300
Gas Sensor (MQ2)	325
LM2596 DC-DC converter	200
Power Supply Circuit (12V)	60
Voltage Regulator	108
Resistor (1kilo ohm)	46
Helix Antenna 433Mhz	130
I2C LCD	394
Switch	40
Buzzer	96
Jumper Wires	200
PCB	345
Total	4680

CHAPTER 5

IMPLEMENTATION DETAILS

5.1 DEVELOPMENT AND DEPLOYMENT SETUP

To Design the Safety Monitoring of Mining Workers Using LoRa- Arduino Nano, WIR-1186 LoRa RF module, Pulse Sensor, Gas Sensor, Vibration Sensor, DHT11 Sensor, Switch, LCD, Buzzer, Voltage Regulator, AC- DC Converter, DC- DC Converter and Helix Antenna are required.

5.1.1 Implementation

Step1: Construction of the circuit:

Connect the Sources:

- Assign which slot you want to place your voltage source (+). I recommend placing it on the lowest side of the breadboard because this is where the conducting plate is fully connected horizontally. Now, connect the jumper wire to the 5V pin of the Arduino board and connect the other end of the jumper wire to the assigned slot that you want to be your voltage source.
- Assign the ground slot (-). I recommend placing it to the lowest side/upper side of the breadboard where the conducting plate is fully connected horizontally but make sure that the voltage pin and ground pin is not connected on the same slot as this will result in a short circuit which could damage your board. Now, connect the jumper wire to the GND pin of the Arduino board and the other end to your assigned ground slot.

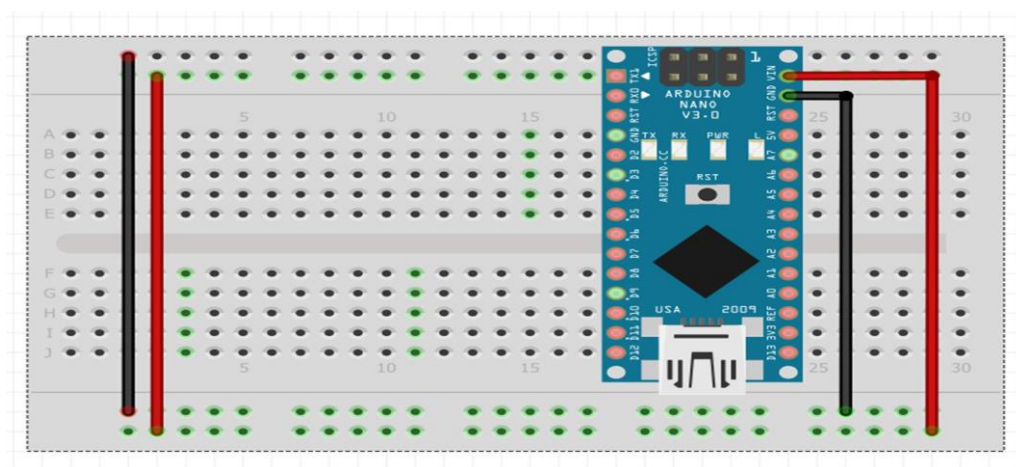


Fig.5.1 Connection between Arduino Nano and Breadboard

Connect the Sensors to Arduino Nano (Transmitter Section):

Table.5.1 LoRa WIR 1186 Connections

LoRa WIR 1186 Pins	Connected to Arduino Nano
CTS	
RXD	
TXD	RX
PRG	
VCC	
GND	

Table.5.1 shows the LoRa WIR 1186 Connections LoRa WIR 1185 module with Arduino nano.WIR-1186 LoRa has 6 pins on one side of this IC circuit. Lora is transmission side and Arduino nano receives the data. The transmission point in lora WIR - 1186 is TXD connected to the RX pin microcontroller Arduino nano for getting information.

Table.5.2 DHT11 Sensor Connections

DHT11 Sensor (Temp/Humidity) pins	Supply	Arduino Nano
+	+ve	
-	-	
Output		A1

Table.5.2 shows the DHT11 Sensor Connections with DHT11 SENSOR is used for temperature and humidity and it has 3 pins namely +, -, output. The + pin connected to +ve power supply and ground to the ground. Output of this sensor is in analog form . So we are connecting output pin into A1 PIN of Arduino Nano.

Table.5.3 Gas Sensor Connections

Gas Sensor Pins	Supply	Arduino Nano
VCC	+ve	
GND	-ve	
Aout	No connection	No Connection
Dout		A1

Table.5.3 shows the Gas Sensor Connections with Arduino nano Gas sensor has an both analog and digital output pins in it along with VCC and GND . VCC pin is connected to +ve power supply and ground to the -ve . It gives an digital output so we didn't made any new connection. DOut is connected to A1 of the Arduino nano.

Table.5.4 Vibration Sensor Connections

Vibration Pins	Supply	Arduino Nano
D0		A2
GND	+ve	
VCC	-ve	

Table.5.4 shows the Vibration Sensor Connections with Arduino nano Vibration sensor is used to measure the vibration in the body has an 3 pins D0, GND, VCC output of the digital is connected to the A2 pin of Arduino Nano and VCC to -ve supply next GND to +ve supply.

Table.5.5 Pulse Sensor Connections

Pulse Sensor Pins	Supply	Arduino Nano
S		A3
+	+ve	
-	-ve	

Table.5.5 shows the Pulse Sensor Connections Pulse sensor which measures the pulse rate has an 3 pins VCC , output and GND pin output pin connects to A3 and VCC to +ve Power supply and GND to -ve.

Table.5.6 Switch Connections

Switch Pins	Connection
+ve	+ve
-ve	Resistor to ground & linked with D7

Table.5.6 shows the Switch Connections Switch has connection as +ve connected to +ve and -ve side connected to the resistor and then to ground linked with the D7

Table.5.7 Arduino Nano Connection

Arduino Nano pins	Supply
Vin	+ve
GND	-ve

Table.5.7 shows the Arduino Nano Connection Arduino nano gets power supply from a battery connect vin of nano board to the +ve and GND to -ve.

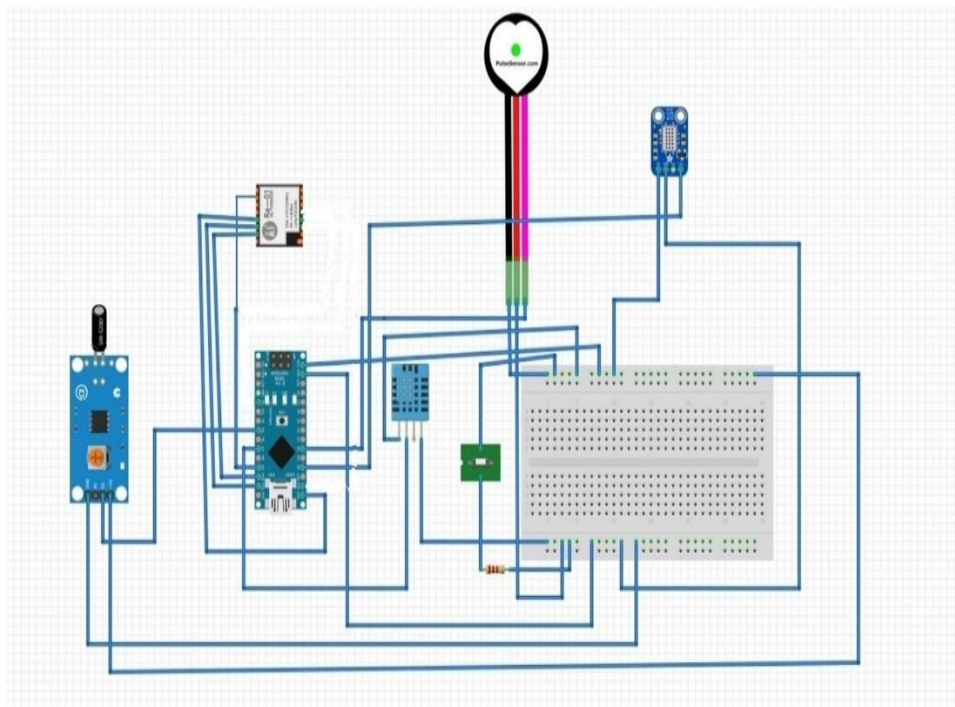


Fig.5.2 Connection between Arduino Nano, LoRa WIR1186 and Sensor(Transmitter Section)

Connections of Repeater Sections:

Table.5.8 Connection between LoRa WIR-1186 and Arduino Nano

(RepeaterSection)	
LoRa SX1278 Pins	Arduino Nano
CTS	
RXD	GND
TXD	TX
PRG	
VCC	5V
GND	GND
POWER SUPPLY	VIN
POWER SUPPLY	GND

In our project we have used 3 LoRa WIR 1186 at transmission section, repeater section and receiver section. Lora power supply pins lora VCC connected to Arduino nano 5v and ground to ground. Lora Rxd pin connected to Arduino nano GND and transmission to the TX pin of Arduino nano. Power supply pins of lora connected to vin and GND of LoRa.

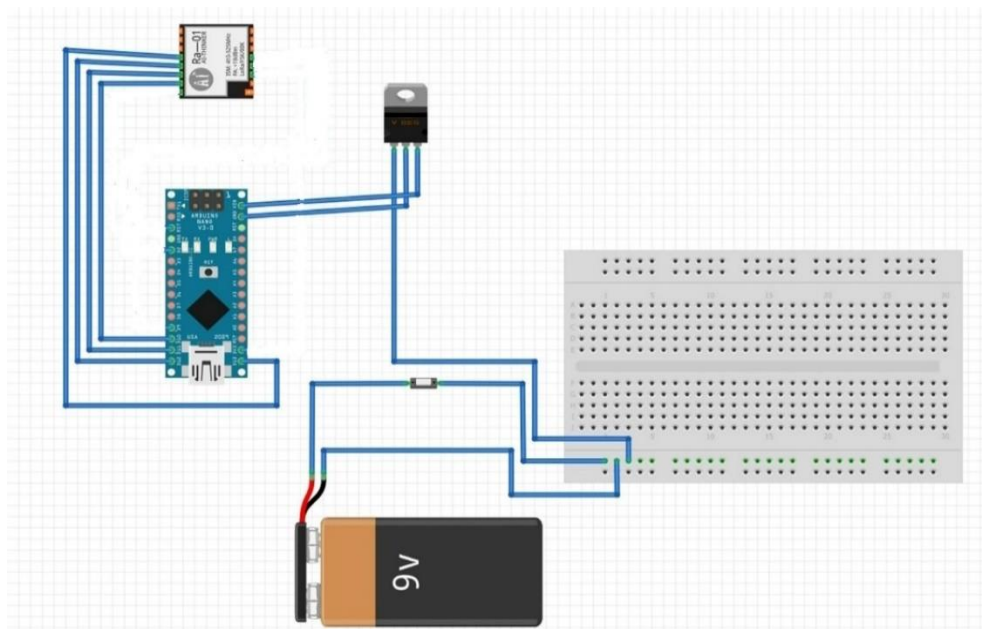


Fig.5.3 Connection between Arduino Nano, LoRa WIR-1186, Voltage Regulator, and Battery (Repeater Section)

Connections of Receiver Section:

Table.5.9 LoRa WIR-1186 Connections with Arduino Nano

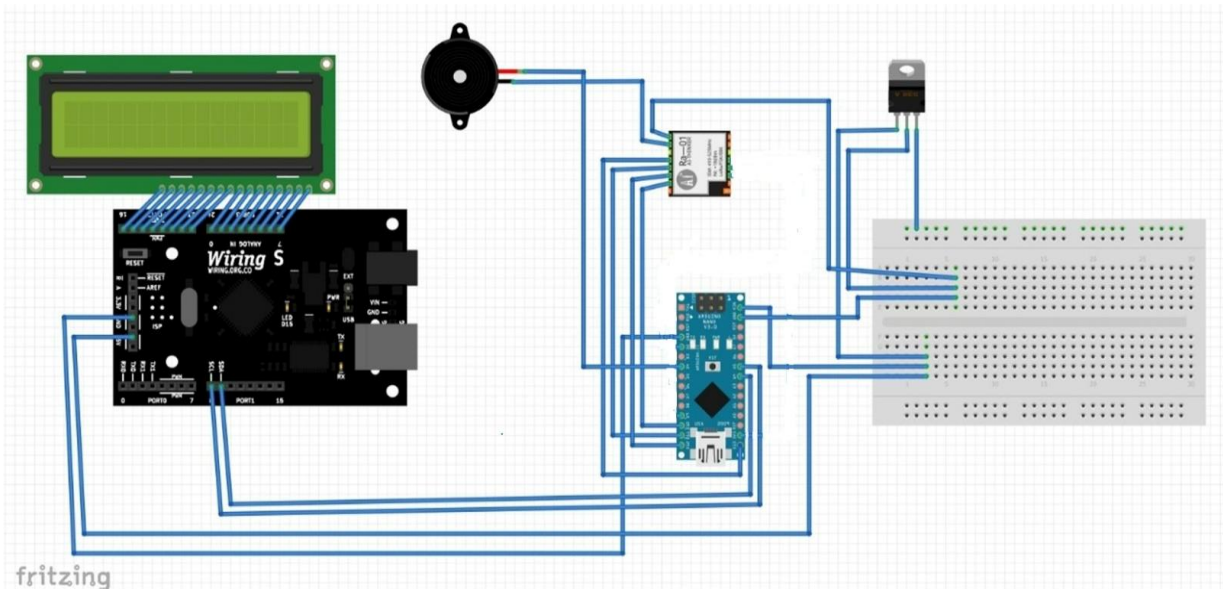
LoRa WIR-1186	Arduino Nano
CTS	
RXD	RX
TXD	TX
PRG	
VCC	Vin
GND	GND

Table.5.9 shows the LoRa WIR-1186 Connections with Arduino Nano the Lora WIR-1186 has 6pins. The RXD of Lora is connected to RX of Arduino, TXD of lora is connected to TX of Arduino nano is used to transmit of data Arduino nano to lora and vcc and ground of Lora is connected to vin and ground of Arduino nano .

Table.5.10 LoRa WIR-1186 Connections With LCD

LCD	Arduino Nano
SDA	A1
SCL	A5
VCC	RST
GND	Vin

Table.5.10 shows the LoRa WIR-1186 Connections With LCD .There are four pins of lcd and they are connected to Arduino nano . SDA of LCD is connected to A1 of Arduino nano and SCL of LCD is connected to A5 of Arduino nano and vcc, ground of LCD is connected to RST and Vin of Arduino. LCD is used to display the various parameters on display.



**Fig.5.4 Connection between WIR-1186, Arduino Nano, Buzzer and I2C LCD
(Receiver Section)**

5.2 ALGORITHMS AND FLOWCHARTS

There are three sections Transmitter, Repeater and Receiver sections.

5.2.1 Transmitter Section: -

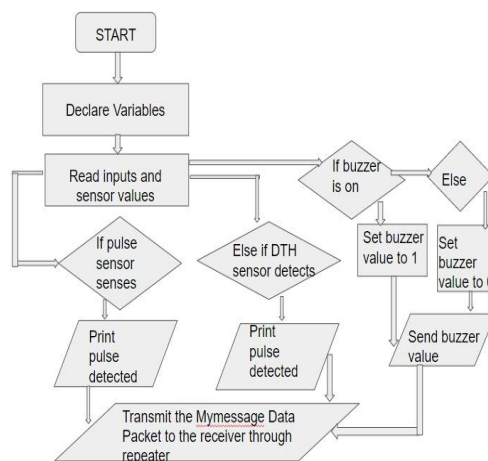


Fig 5.5Flow chart of Transmitter Section

Initially the variables are declared and the inputs are taken as required. Fig 5.5 shows the Flow chart of Transmitter SectionThe inputs would be taken from the sensors for the BPM, Temperature and Humidity. Each time we would be checking for the input from the BPM sensor. Now whenever there is an input from the BPM sensor, we print the line “♥ A Heartbeat Happened!” and print the BPM value. Next on the loop we would be checking for the inputs from DHT11 sensor and assign

each of the temp and humidity values. On the next go we would check the if we have got any values from the sensor and if not, we would print “Failed to read from DHT sensor!”. Finally we would give a variable named My mesaage which will contain all the sensor values in a single message putting out the BPM value, Temp and humidity. Also check for buzzer value and if the victim presses it set the buzzer value to 1 and transmit it further else set it to 0 and transmit it further. This variable My message would be transmitted further on this transmitter section.

5.2.2 Repeater Section: -

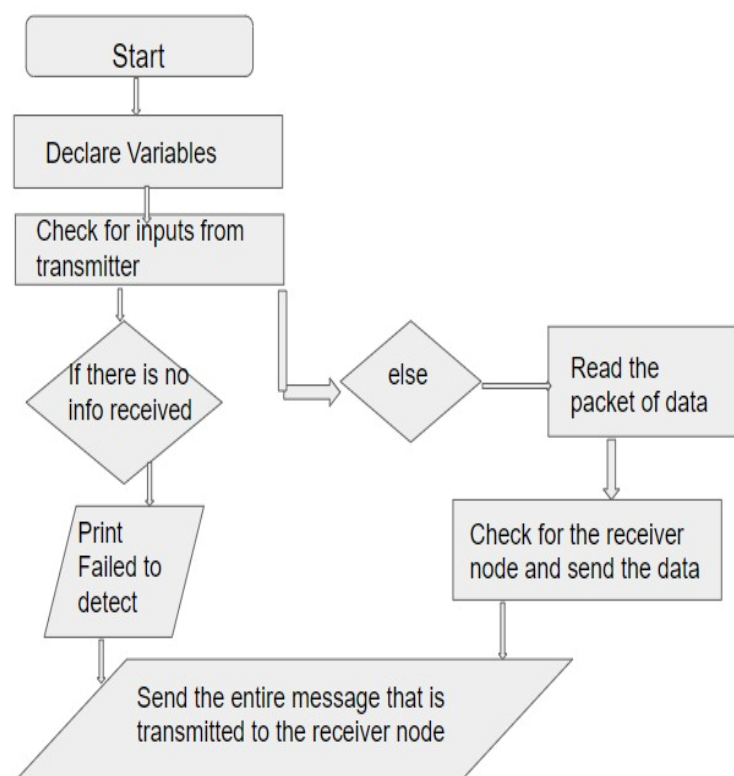


Fig.5.6 Flow chart of Repeater Section

Fig.5.6 shows the Flow chart of Repeater Section. This section is used for the message to be transmitted over longer distances. Since there would be losses in the signal during transmission over longer distances, we use a repeater in between so the signal would be grabbed by this section and set again to the receiver hence not letting the signal to be lost. In our project the repeater receives the signal from the transmitter and then fetches the receiver node thereby sending it the packet of data to the receiver.

5.2.3 Receiver Section: -

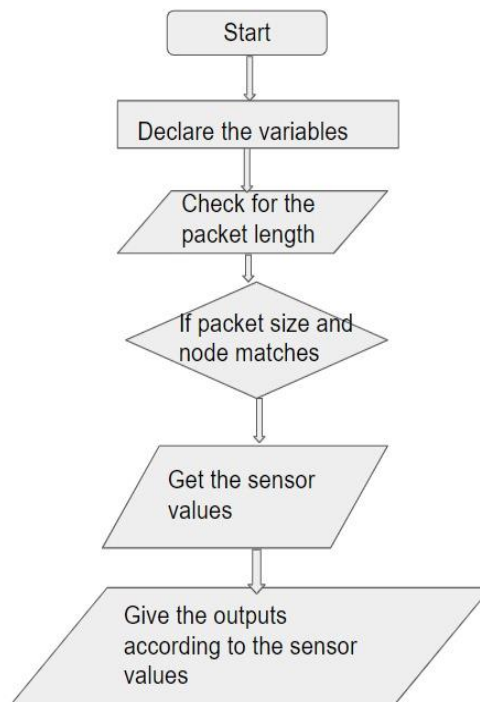


Fig.5.7 Flow chart of Receiver Section

5.7 shows the Flow chart of Receiver Section At the receiver end the message that is received is checked for its length and nodes and if all the details match the sensor values are read and taken as inputs and according to the messages transmitted and the buzzer values given by the sender the values are represented at this end and parallelly the buzzer and alarms are set high or low.

CHAPTER 6

RESULTS AND DISCUSSION

The proposed system consists of three sections namely Transmitter Section, Repeater Section, and Receiver Section. Transmitter Section Consists of various sensors like Pulse Sensor, Gas Sensor, Vibration Sensor, and DHT11 Sensor which are connected to the Arduino Nano and Arduino nano drives all the parameter values to the Lora which is connected to the Arduino itself. The transmitter section also consists of a switch that helps the person to trigger an alarm which is placed in the receiver section in case of emergency.

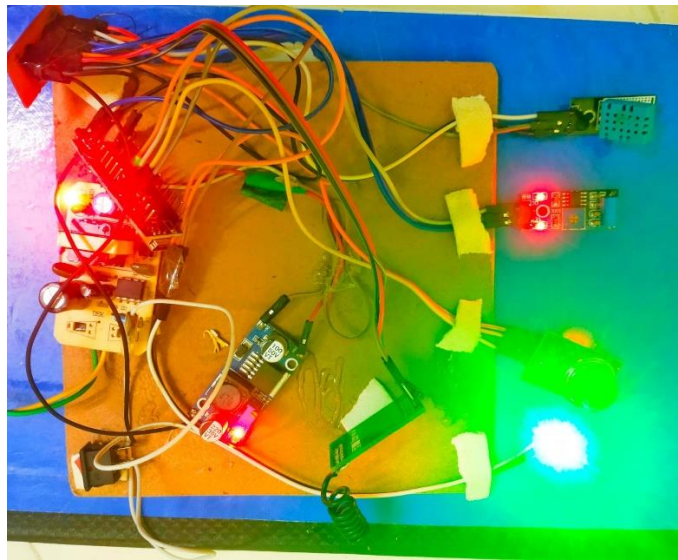


Fig.6.1 Transmitter Section

Fig.6.1 shows the Transmitter Section All sensed values from different sensors are received by the Lora and transmitted to the second Lora which is present in the Repeater section. Here the Lora used is half-duplex so it cannot transmit or receive information simultaneously. So to get both actions done an Arduino Nano is used which activates the Lora connected to it and helps in both transmitting and receiving the information. Fig.6.2 shows the Repeater Section The Repeater section is used in order to increase the range of communication between transmitter and receiver.

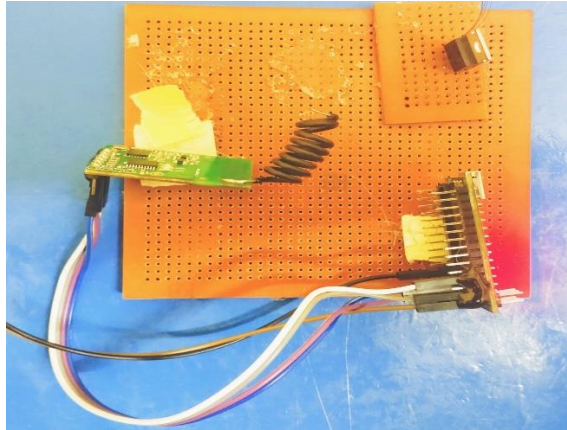


Fig.6.2 Repeater Section

Fig.6.3 shows the Receiver Section. The received information in the repeater section is further transmitted to the receiver section. All the information transmitted from the repeater section is received by the third LoRa present in the receiver section which consists of the buzzer and LCD. The values of the different parameters are displayed continuously on the LCD screen which helps the person in the control room to monitor the health condition of a miner and surrounding parameters.

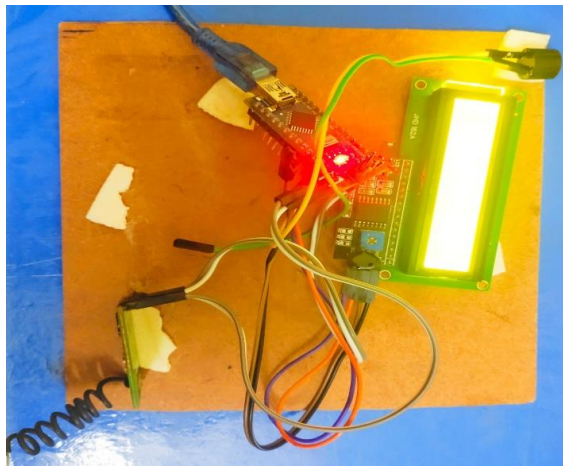


Fig.6.3 Receiver Section

Fig.6.4 shows the Working Model of “A Safety Monitoring System for Mining Workers Using LoRa”. This is the final output of a safety monitoring system for coal mine workers using LoRa, having three sections like transmitter section, repeater section, and receiver section.

Fig 6.5 shows the Displayed of Various Parameters on Liquid Crystal Display. Whatever the sensed parameters (transmitter section) sensed by various sensors like vibration sensor, gas sensor, pulse sensor, and temperature and humidity sensor

are displayed on liquid crystal display(receiver section).

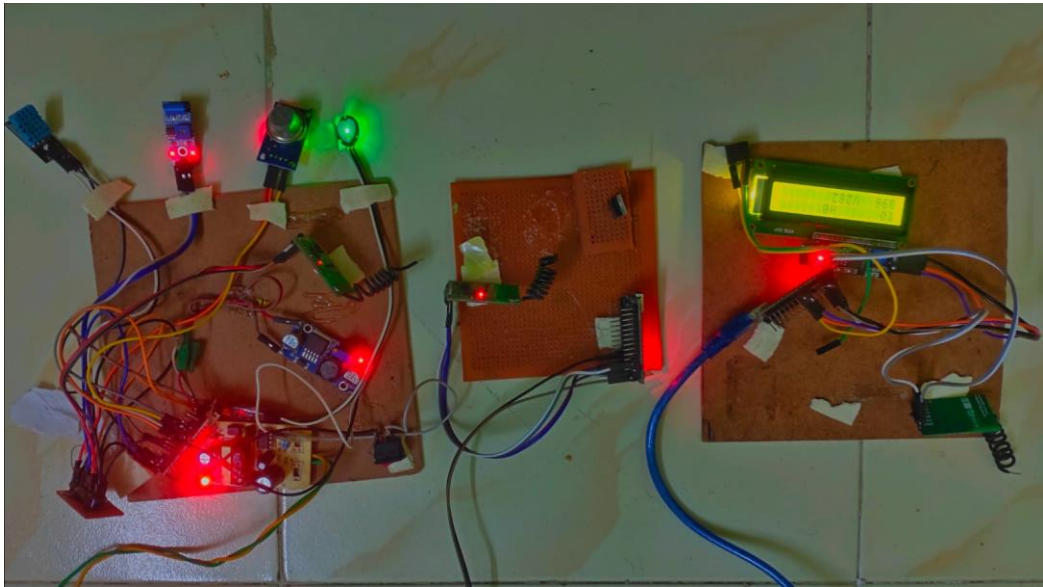


Fig.6.4 Working Model of “A Safety Monitoring System for Mining Workers Using LoRa”



Fig.6.5 Display of Various Parameter

Advantages and Disadvantages

Advantages:

- The range of the system can be increased by adding additional repeater sections.
- Effective maintenance and reduced complications.
- 10 to 100 times higher precision, avoiding human errors.
- It gives spontaneous output.

Disadvantages:

- The system requires a permanent power supply.
- It Requires full-time supervision by the operator.

CHAPTER 7

CONCLUSION

7.1 CONCLUSION

The aim of this model is to ensure safety of the miners working in harsh conditions. In this system various parameters are considered for monitoring the health condition of the person and surrounding conditions using various sensors. Literature survey is performed on all the existing models and designed a system where the range of communication is increased and the software used is Arduino IDE. So, the main hardware components are LoRa, Arduino Nano and various sensors like temperature, vibration, pulse and gas which gives the readings of the person and the mine conditions. In this, we have increased the range of communication up to 2 km and it can be increased further by adding a few more repeater sections. The system is of low cost and can be implemented easily.

7.2 FUTURE WORK

LoRa (Long Range) is a low-power, wide-area network (LPWAN) technology that enables long-range communication between devices. It is an ideal technology for applications that require low-power, long-range communication, such as safety monitoring systems for coal mining workers.

One potential future work in safety monitoring systems for coal mining workers using LoRa could be the development of more advanced sensor technology that can detect a wider range of hazards. For example, sensors could be developed that can detect dangerous levels of gases, such as methane, carbon monoxide, and hydrogen sulfide. These sensors could then communicate the data to a central monitoring system via a LoRa network.

Another potential future work could be the integration of LoRa with other communication technologies, such as satellite and cellular networks, to ensure reliable communication even in remote areas where LoRa coverage may be limited. This could help to ensure that the safety monitoring system is always operational and able to provide real-time data on the safety conditions for coal mining workers.

Additionally, there is also room for improvement in the design of the safety

monitoring system itself. For example, the system could be made more user-friendly and easier to operate, allowing coal mining workers to quickly and easily access safety data and alerts in case of an emergency.

Overall, there are many potential future works that could be explored in the area of safety monitoring systems for coal mining workers using LoRa technology. By continuing to develop and improve these systems, we can help to ensure the safety and well-being of coal mining workers, and reduce the risks associated with this dangerous but essential occupation.

7.3 RESEARCH ISSUES

The research process for developing a safety monitoring system for mining workers using Lora technology involves several challenges. The literature survey involves the analysis of various academic and industry publications to gain a comprehensive understanding of the current state of the art in the field. The major issue in this stage is the availability of limited research work specifically focused on the implementation of Lora in the mining industry for safety monitoring. Additionally, research on devices and systems that are compatible with Lora technology is crucial, and finding the appropriate devices and systems that can withstand the harsh mining environment can be a challenge. The deployment methods of the setup also need to be carefully considered to ensure effective data communication and reliable operation in a complex underground environment. Overall, the research for this project requires a thorough investigation of various aspects, and the ability to adapt to new and unforeseen challenges is essential to ensure the successful development and deployment of the safety monitoring system.

7.4 IMPLEMENTATION ISSUES

Implementing a safety monitoring system for mining workers using LoRa can present various challenges during development and deployment. One of the main issues could be the complexity of the system, which would require a significant number of resources, time, and expertise to develop and deploy. Additionally, the system's sensors and devices would need to be designed to withstand the harsh environmental conditions and radio interference typical of mining operations. Another challenge could be integrating the LoRa technology with existing mining equipment and infrastructure. To ensure the system's reliability, extensive testing

and validation would be required before deployment. Moreover, the system's security would need to be taken into consideration to protect sensitive data and prevent unauthorized access. Overall, these implementation issues highlight the importance of careful planning and execution during the development and deployment of the safety monitoring system for mining workers using LoRa.

REFERENCES

- [1] U. Raza, P. Kulkarni and M. Sooriyabandara. (2017). "Low power wide area networks: An overview," IEEE Communications Surveys & Tutorials, vol. 19, no. 2, pp. 855–873.
- [2] Y. Liu, Z. Wang and Q. Peng. (2012). "Design and implementation of remote wireless meter reading system based on ZigBee and GPRS," Science Technology & Engineering, vol. 12, no. 30, pp. 8058–8062.
- [4] W. Di, C. Ling, G. Lili, W. Yimei and J. Xuesong. (2017). "Application research of ZigBee protocol in CPS based on multiagent," in 2017 29th Chinese Control and Decision Conference (CCDCChongqing, China, pp. 6843–6846
- [5] D. Heeger, M. Garigan and J. Plusquellic. (2020). "Adaptive data rate techniques for energy constrained Ad Hoc LoRa networks," in 2020 Global Internet of Things Summit (GIoTSDublin, Ireland, pp. 1–6.
- [6] A. Zourmand, A. L. Kun Hing, C. Wai Hung and M. Abdul Rehman. (2019). "Internet of Things (IoT) using LoRa technology," in 2019 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACISSelangor, Malaysia, pp. 324–330.
- [7] T. Zhuang, M. Ren, X. Gao, M. Dong, W. Huang et al. (2019). , "Insulation condition monitoring in distribution power grid via IoT-based sensing network," IEEE Transactions on Power Delivery, vol. 34, no. 4, pp. 1706–1714.
- [8] C. Liao, G. Zhu, D. Kuwabara, M. Suzuki and H. Morikawa. (2017). "Multi-hop LoRa networks enabled by concurrent transmission," IEEE Access, vol. 5, pp. 21430– 21446.
- [9] C. Liao, G. Zhu, D. Kuwabara, M. Suzuki and H. Morikawa. (2017). "Multi-hop LoRa networks enabled by concurrent transmission," IEEE Access, vol. 5, pp. 21430– 21446.
- [10] R. A. Kjellby, L. R. Cenkeramaddi, A. Frøytlog, B. B. Lozano, J. Soumya et al. (2019). , "Long-range & self-powered IoT devices for agriculture & aquaponics based on multi-hop topology," in 2019 IEEE 5th World Forum on Internet of Things (WF- IoT Limerick, Ireland, pp. 545–549.

- [11] M. S. Aslam, A. Khan, A. Atif, S. A. Hassan, A. Mahmood et al. (2020), "Exploring Multi-Hop LoRa for green smart cities," *IEEE Network*, vol. 34, no. 2, pp. 225–231.

- [12] T. Porselvi, S. G. CS, J. B, P. K and S. B. S, "IoT Based Coal Mine Safety and Health Monitoring System using LoRaWAN," 2021 3rd International Conference on Signal Processing and Communication (ICPSC), Coimbatore, India, 2021, pp. 49-53, doi: 10.1109/ICSPC51351.2021.9451673.

- [13] P. Hazarika, "Implementation of smart safety helmet for coal mine workers," 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), Delhi, India, 2016, pp. 1-3, doi: 10.1109/ICPEICES.2016.7853311.

- [14] Suganya, R., & Gowtham, S. (Jan 2021). Individual Health and Safety Monitoring of Workers in Deep Underground Mines Using IOT. *Journal of Physics Conference Series (Online)*, 1717(1), 7. doi:10.1088/1742-6596/1717/1/012044

- [15] Poornima, Mrs & Sai, T.. (2020). Coal Mine Monitoring System using Arduino and Lora. *International Journal of Soft Computing and Engineering*. 10. 10-13. 10.35940/ijscce.A3438.0710120.

- [16] R. K. Kodali and S. Sahu, "IoT based Safety System for Coal Mines," *2018 International Conference on Communication, Computing and Internet of Things (IC3IoT)*, Chennai, India, 2018, pp. 147-150, doi: 10.1109/IC3IoT.2018.8668184.

